Volume 13 FEBRUARY 1929 Number 2

# BULLETIN

*of the*

# American Association *of* Petroleum Geologists

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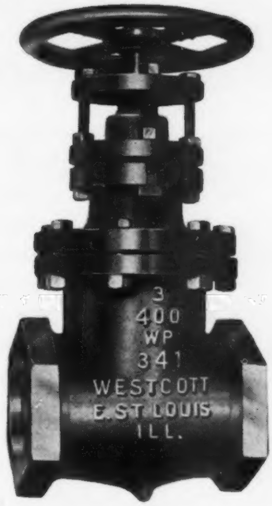


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## AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS




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By BRUCE L. CLARK

*Annual Audit of Association Accounts*

*Association Membership List*

Volume 13 Number 2

# BULLETIN

*of the*

# AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

FEBRUARY 1929

## STRUCTURAL FEATURES OF THE EAST SIDE OF THE SAN JOAQUIN VALLEY, CALIFORNIA[1]

LEO S. FOX[2]
Los Angeles, California

ABSTRACT

Normal faulting is the dominant feature in the structural history of the east side of the San Joaquin valley in the Kern River district, with general downthrow movements of crustal blocks toward the west. These movements have continued or have been intermittently renewed from early Miocene to Recent time, with a consequent effect on sedimentary distribution.

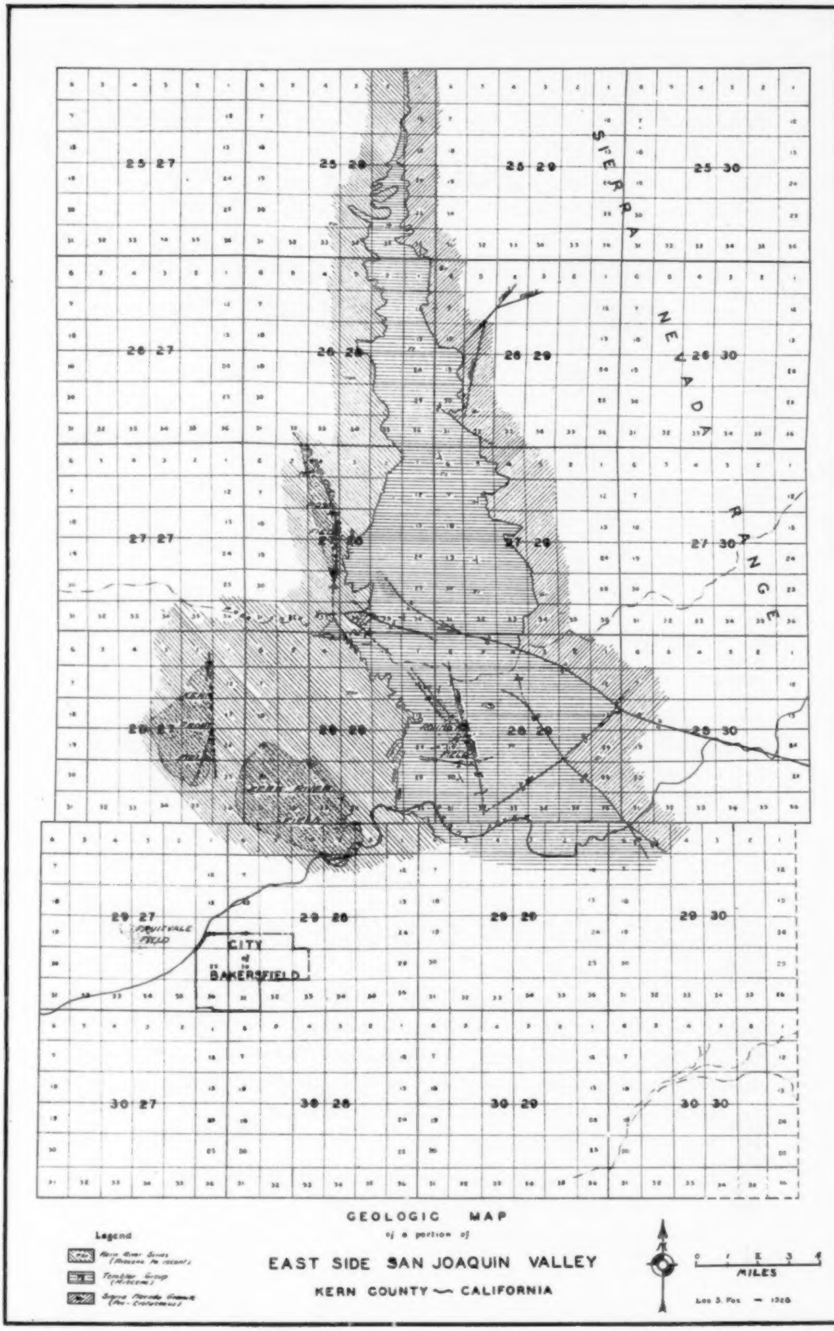
A continuation of the system of block faulting evidenced in the granitic mass on the western slope of the Sierra Nevada range can be seen on the gently-dipping sediments along the fringe of the valley, although of less intensity. Farther out in the valley, where structural details can not be determined by outcrops, topographic evidence points to these same tensional forces at work, possibly accentuated by overloading of sediments as the valley is being filled.

Wildcatting activities, accompanied by exhaustive geological investigations in the past few years, have brought to light some interesting facts regarding the structural and sedimentary history of the east side of the San Joaquin valley.

Faulting is the dominant feature in the structural history of this side of the valley in the foothill region adjacent to Bakersfield (Fig. 1). Its direct relation to and control of the accumulation of oil in this vicinity has made a close study of the fault systems of great importance. This relationship of faulting to oil accumulation has been clearly demonstrated by the discovery of oil in the Temblor group, middle Miocene, of the

[1]Read before the Association at the San Francisco meeting, March 28, 1928. Manuscript received by the editor, November 20, 1928.

[2]Geological department, General Petroleum Corporation.



GEOLOGIC MAP
of a portion of
EAST SIDE SAN JOAQUIN VALLEY
KERN COUNTY — CALIFORNIA
Legend
MILES
SIERRA NEVADA RANGE
CITY of BAKERSFIELD
FRUITVALE FIELD
KERN RIVER FIELD


FIG. 1

Mt. Poso and Round Mountain fields. The very probable relationship of faulting to the accumulation of oil in the Kern River series farther out in the valley has given impetus to much conjecturing regarding the location of fault lines where no outcrops are present as proof of displacements.

The sedimentary history of the Bakersfield region begins in early Miocene time with the deposition of the lowest member of the Temblor group, locally called the Walker formation, probably the equivalent of the Vaqueros, a formational name of more general use in California nomenclature. This depositional era is represented by about 700 feet of variegated clay shales, volcanic ash beds, and ill-sorted sands and conglomerates, in the main of fresh- or brackish-water origin. Above this are deposited marine and brackish-water shales and sands, the sandy facies predominating, equivalent in age to the Monterey shales of other localities in California, and including, in its upper member, beds of Santa Margarita age. So far as known, the group attains in this area a maximum thickness of more than 3,000 feet. Resting unconformably on the Temblor is the Kern River series, which consists of unconsolidated sands and clays of fresh-water origin, and, in its more basinward phase, of interstratified marine Etchegoin sediments. At numerous places along the eastern fringe of the valley these beds are lacking, but farther west they increase in thickness to several thousand feet within a short distance. These Kern River beds represent the entire series of deposits from early Pliocene to Recent time.

An east-west profile of the Sierra Nevada Mountains shows the range to be a long tilted block, dropping off sharply along its eastern escarpment, and with a more gradual slope toward the west. The structural features present in the sediments west of the range can be seen to be a reflection in miniature of the orogenic movements of the Sierra Nevada.

A study of the western slope of the Sierra Nevada range and the adjacent strip of the valley in the Kern River district shows the region to be one of normal faulting, in which tensional stresses have caused a tilting of crustal blocks, in general with downward movements toward the valley. The major lines of faulting are predominantly parallel with the mountain range, but are accompanied by related displacements approximately at right angles to the major rifts. The system of block faulting thus described can be readily observed in the granite mass east and southeast of Bakersfield. Bear Mountain presents a tilted block with prominent escarpments on the northeast and southwest sides, and, in the writer's opinion, Bear Valley and Cummings

Valley, on the south, represent the lower parts of this tilted block. Walker Basin is a dropped block southeast of Mt. Breckenridge, with a prominent north-south fault escarpment between the two. With the tilting and differential oscillation of these granitic masses as an example, it is easy to conceive of similar forces at work in the igneous rocks underlying the sedimentary beds along the eastern fringe of the valley.

In general, basinward from the granite, a series of graben-like blocks is found roughly paralleling the mountain face. The faults which bound these downthrown blocks on the east differ as to position. Some of them occur at the contact of the granite and the sediments. Others have occurred either behind or in front of the normal contact of granite and sediments, but very close to it. Other faults which constitute the eastern limit of these blocks are some distance back in the granite.

Westerly from the first major line of motion showing in the sediments, successive, more or less elongate, and approximately parallel blocks appear to be rotated downward toward the valley. Of this there is no absolute proof beyond a distance of a few miles from the mountains, due to the obscuring of structural details by a covering of younger beds. It is known, however, that along the first major lines of displacement away from the granite, the downthrown sides of the faults are generally on the east. Farther out in the valley, topographic evidence exists which leads the writer to believe that similar conditions prevail. There is, therefore, a system of approximately parallel faults along which successive blocks are dropped and rotated on axes parallel with the lines of weakness, in such a manner as to produce downthrows on the mountainward sides of the fault planes. Uniform motion and uniform direction along these major lines of weakness necessarily do not exist, due primarily to their interruption by transverse breaks; and local conditions are known to exist in which the order of motion is reversed.

During the period of the deposition of the sedimentary beds, the tensional forces causing the faulting continued to be active. Both the character and the thickness of the beds of the Temblor group have been partly governed by the faulting. A distinction may possibly be drawn, therefore, between the movements in the foothill region near the mountains, and disturbances farther out in the valley floor, the former being caused entirely by orogenic movements, and the latter by the mountain movements combined with those caused by the differential loading of the old blocks. In the foothills, prolonged and intermittent disturbances have followed lines of weakness in the underlying rock masses, and the faulting has been a factor in controlling the local varia-

tions in sedimentation. Farther out in the valley, however, the basinward faults, more distant from the tensional strains of mountain movement, instead of being a cause of sedimentary distribution, may be more directly the effect of sedimentation, the ever-increasing load of valley fill renewing motion on previously established fault lines.

That faulting has had a direct bearing on the distribution of the Temblor sediments along the fringe of the valley is best demonstrated by a consideration of the thickening of these beds from north to south along a line approximately parallel with the granite face, and a few miles away from it. North of the Tulare County line the Temblor beds do not crop out, being completely overlapped by the Kern River series which rests directly on the granite. Southwest of this locality, and about 5 miles from the granite, the Temblor group, as evidenced by coring in the Chanslor, Canfield, and Midway Oil Company's "Delano" well, is found to be approximately 1,100 feet thick. From this point southeast the Temblor becomes gradually thicker; at Round Mountain it is represented by about 4,000 feet of beds, including the lower fresh-water member; and evidently is still thicker farther south, the center of the old re-entrant basin of Temblor time probably being several miles farther south than Round Mountain. It is evident, therefore, that the Temblor basin was much deeper adjacent to the present land mass in the southern end of the valley than farther north. Likewise, field evidence would lead to the belief that the faulting has been more intense adjacent to Kern River than in the northern region. Accordingly, deeper basins were formed at an equal distance from the present granite contact in the southern part of the valley.

Evidence of continued, or at least intermittently renewed, disturbances during sedimentary deposition is the presence of local unconformities within the Temblor group. In one place, the writer found a water-worn oyster redeposited in a pebble bed, and 200 feet stratigraphically higher than its normal position in the geologic section. Another significant fact noticed in the field is that several faults located and traced for some distance in the Temblor beds are of less magnitude in the overlying Kern River beds.

Where faulting occurs in the Temblor it is clearly evident in exposures. The breaks are ordinarily sharp and well defined. Except in certain shaly members of the Temblor, where the displacements consist of a series of cumulative breaks in a narrow zone, the actual fault plane may be definitely located. Where found, the faults have an average hade ranging from 20° to 25°. Observations on the faulting in the sed-

iments reveal a lack of steep dip and, in many places, a lack of reverse dip along the displacements. The beds have been broken with very little departure from the regional dip. The Temblor sediments ordinarily dip toward the valley at an angle no greater than 10°, and with an average of approximately 6°, in a southwesterly or southerly direction. The regional dip of the Kern River beds is somewhat less, rarely exceeding 5° and averaging 3.5°. Where the beds are cut by faults of small displacement, a change in the dip of the beds extends only a few feet on either side of the displacement. In faults of greater magnitude, the drag rarely extends 100 feet away from the fracturing, and the strata gradually resume their normal dip. This very apparent uniformity of dip is probably due to two causes: (1) the preponderance of arenaceous sediments, causing sharp breaks with a minimum amount of contortion because of the lack of cohesion in the materials composing the beds, and (2) the fact that the tensional forces producing the displacement have not acted violently within a short period of time, but gradually through a very long period.

Displacements observed in the Temblor sediments differ greatly in amount, but few exceed 500 feet along any one fault line. Along a major line of weakness parallel with the mountain range, many cumulative displacements in a narrow zone may attain this maximum, but few exceed it. The Round Mountain fault, well known because of its relation to oil accumulation, has a maximum displacement estimated at 350 feet. An equal amount is estimated to be the maximum on the Mt. Poso fault.

In the Temblor sediments adjacent to the granites, there are many examples of cross faulting. This is only natural if the conception of structure in the underlying rocks is correct,—that of tilted blocks under tensional strain. One such fault exists east of Round Mountain, trending southwesterly from the granite into the Temblor beds. Several others have been followed until lost, in so far as actual outcrops are concerned.

That earth movements continued after the period of deposition of the lower Kern River series is shown by the displacements observed in these beds. There is ample evidence of this in the vicinity of the Mt. Poso fault. Where noticed, the fracturing has the same general characteristics as that seen in the Temblor beds. No displacements in outcrops have been seen by the writer in the upper Kern River and more recent sediments, although certain topographic expressions are prevalent from which conclusions may be drawn that movements continued

through upper Kern River and more recent time. Two conditions exist which tend to obscure any evidence of faulting: (1) the lack of good outcrops, and (2) the surface washing of rock basement faults by adjustments within the loose rock mantle. Certain phenomena of drainage and other topographic expression leave little doubt that movements have taken place, recently enough to have affected and, in many places, to have controlled the courses of the younger drainage systems.

One of the best examples of the effect of faulting on the drainage may be seen along the Mt. Poso fault. This fault may be traced southward from the Mt. Poso field for a distance of approximately 6 miles, and its surface trace accurately mapped. It is found that the fault trace is approximately parallel with a deep drainage on the east. West of this drainage there is a high divide parallel with the displacement, the fault being located between the two. Short drainage systems extend eastward off this divide into Granite Canyon, and long drainage systems extend from the divide in a southwesterly direction, in part influenced by the strike of the gently-dipping Kern River beds. A very definite relationship can therefore be found between this fault and the topographic relief adjacent to it. Other examples as convincing could be cited, in which the same general conditions prevail. It has been observed that in localities where the relief is great there is a pronounced relationship between the faulting and the drainage, although at first glance this may be overlooked. Many faults seemingly cut across canyons and ridges without leaving any topographic evidence. Closer study will ordinarily reveal the fact that the movements have caused differences in elevation on opposite sides of the fault, and a rectangular alignment of the drainage system.

Going farther out in the valley, where fault displacements can not be traced in the beds themselves, the drainage pattern is such as to lead the writer to believe that the same conditions prevail that are present closer to the mountains, and that movements have continued along preexistent fault planes up to very recent time.

In summary it may be observed that normal faulting is the dominant feature in the structural history of the east side of the San Joaquin valley in the Kern River district, with general downthrow movements of crustal blocks toward the west. These movements have continued or been intermittently renewed from early Miocene to Recent time, with a consequent effect on the distribution of sediments. A continuation of the system of block faulting evidenced in the granitic mass on the western slope of the Sierra Nevada range can be seen in the gently-dipping sed-

iments along the fringe of the valley, although of less intensity. Farther out in the valley, where structural details can not be determined by outcrops, drainage evidence indicates that these same tensional forces have been active up to Recent time, the overloading of the old fault blocks by younger sediments as the valley was being filled having possibly been a factor in renewing motion.

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## DISCUSSION

Hoyt Rodney Gale: What is the evidence to support the statement that the faulting found is normal tensional faulting rather than compressional?

Leo S. Fox: By definition, a normal fault is one in which the fault plane is inclined in the direction of the downthrown side of the fault, the hanging wall having slipped down with respect to the foot wall. All of the displacements observed by the writer in the sediments on the east side of the San Joaquin valley are of this type. Further, the lack of steep dip in the beds, the lack of repetition of beds in vertical sections, and the lack of contortion and pronounced folding indicate that the movements which have taken place are demonstrably due to tension, rather than compression.

F. M. Anderson: A well-developed fault traverses the border of the granite and crosses Kern River at the contact of the sedimentary rocks. It extends from the mouth of Walker Basin Creek northwesterly for three or more miles north of Kern River, where it merges into a syncline which continues beyond Paso Creek. A well-defined anticline parallels this fault, about a mile east of the discovery well at Round Mountain. How would the writer explain this anticlinal fold on the theory of tensional faulting? Is it not rather an evidence of compression?

Leo S. Fox: The writer has observed the folding east of Round Mountain. The area is cut by several faults, however, and it is the opinion of the writer that the reversals in dip are due to the dragging down of the beds along these displacements. Although this action may produce local compression within an individual fault block, it is still directly attributable to regional tensional strain.

# COURSES OF DRILL HOLES[1]

MARTIN VAN COUVERING[2]
Los Angeles, California

ABSTRACT

The investigation into the courses of drill holes, reported in this paper, has shown that several different factors are causes of deflections from the vertical, the principal causes being the application of too much pressure to the drilling bit and the disposition of the bit to follow down the dip of the strata. As a result, wells drilled in good locations at the surface may be deflected into unproductive formations, or the opposite may be true. Correlations based on the assumption that all drill holes are vertical may be extremely misleading, especially where great depths are attained. No means are known at present which will assure the drilling of vertical holes or the deflection of holes in predetermined directions.

ACKNOWLEDGMENT

In the compilation and interpretation of data for this paper, assistance which was indispensable was received from many operators, particularly from geologists. Especial appreciation is due Quay Diven of the Associated Oil Company, who made many valuable suggestions. In so far as his responsibilities to his clients would permit, Alexander Anderson assisted with suggestions and criticisms. As the inventor and operator of hole-surveying instruments, he is in a position to have more data than anyone else, but the pressing demand for his services makes it impossible, at the present time, for him to make the thorough analysis which he alone can make. It is to be hoped that he will soon be able to do this.

## INTRODUCTION

The matter of the courses taken by holes drilled for the purpose of making oil wells probably transcends in importance any other factor which has entered into drilling practice since the introduction of the core barrel. In fact, the surveying of these courses and the taking of core samples go hand in hand.

The knowledge that nearly all bore holes are deflected from the

[1]Read before the Pacific Section of the Association at the Los Angeles meeting, November 2, 1928. Manuscript received by the editor, November 17, 1928.

[2]Petroleum engineer, Petroleum Securities Building.

vertical introduces a problem. The surveying of the holes offers the solution.

It is believed that the knowledge gained from these surveys will have a revolutionary effect on drilling practice. This effect is already beginning to be felt. Most of the holes which have been drilled in California in the last few years have been so situated that they might easily migrate from under the properties upon which the drilling was commenced. This well-known fact is inducing the operators to seek means of keeping the direction of their drill holes vertical.

Obviously the productivity of a well is profoundly affected by the course followed by the drill hole. The departure from the vertical introduces several mechanical problems, such as wear on the drill pipe, the casing, and the sucker rods, and the pumping of mud or cement from one well into another. This is true even though few holes have such sharp changes of direction as to justify their being called "crooked holes."

### APPARATUS FOR SURVEYING DRILL HOLES

Up to the present most of the surveys have been made with the equipment invented and operated by Alexander Anderson of Fullerton, California. This consists essentially of a piece of casing, which is fitted to the end of the drill pipe and which has a rounded point on the bottom end. This contains a device for making a photographic record of the inclination of the hole from the vertical.

The direction in which the hole migrates is determined by measuring at the surface the horizontal angle through which the drill pipe rotates as each stand passes into the hole. The reliability of such a method is often called in question by those not familiar with it, but this is not the occasion for a discussion of this question. It is sufficient to say that its surprising accuracy has been checked on several occasions, and that the major companies are convinced sufficiently to make frequent use of Anderson's equipment.

### WHAT THE SURVEYS SHOW

After each survey Anderson provides the operator with (1) a plan view showing the directions in which the hole has meandered, (2) two vertical sections taken at right angles to each other, showing the deviation from the vertical, and (3) a table of information obtained through the survey, including the footage drilled, the corresponding vertical depth from the surface, and related information.

In the course of this investigation not one drill hole was found to be strictly vertical. It is highly improbable that any such exist. Most of

the plan views show wavering courses. Some show a clockwise direction, but about as many show that the principal direction is counter-clockwise. In several courses there is a reversal of direction in a single hole. Many of the holes surveyed are deflected in a fairly straight line in one direction only.

Considered in the vertical plane, most of the wells go down fairly straight until a depth of 3,000 or 4,000 feet is reached, where they gradually increase their deflections from the vertical as the depths increase. In some holes, which have departed considerably from the vertical, their directions are reversed and they again approach positions directly beneath the derricks.

It is difficult for even a technically trained man to visualize correctly the course of a bore hole with the aid only of drawings in two dimensions. It is, of course, not practicable for Mr. Anderson to provide his clientele with more data than is now furnished, but it is desired to call attention to the advantages of models showing the courses of the surveys in three dimensions.

Such a model, having a scale of 100 feet to the inch, has been prepared for use in connection with this paper (Fig. 1). A copper wire has been threaded through this model to represent the course of the drill hole as shown in each of four wells.

None of the ideas in the construction of this model is original, but it is believed that many geologists and petroleum engineers have not had an opportunity to study a model of this kind, especially where more than one well is represented.

It is believed that no one familiar with the plan view of any survey would recognize it in the three-dimensional model. The mental impressions created in the two cases are totally different. For this reason, the plan views of the surveys are criticised by many on the ground that it would be impossible for the drill pipe to negotiate the sharp changes in direction shown in these drawings. Very few persons can imagine the third dimension in its true proportion.

Miniature oil derricks, whose height conforms to the scale of the model, have been placed on an imaginary topography at the top of the model in order to assist in visualizing the depths of the wells and the slenderness of the drill pipe in proportion to its great length.

### REASONS FOR DEFLECTION FROM THE VERTICAL

In the present survey a very earnest attempt was made to determine the factors which cause the drill pipe to be deflected from a vertical line.

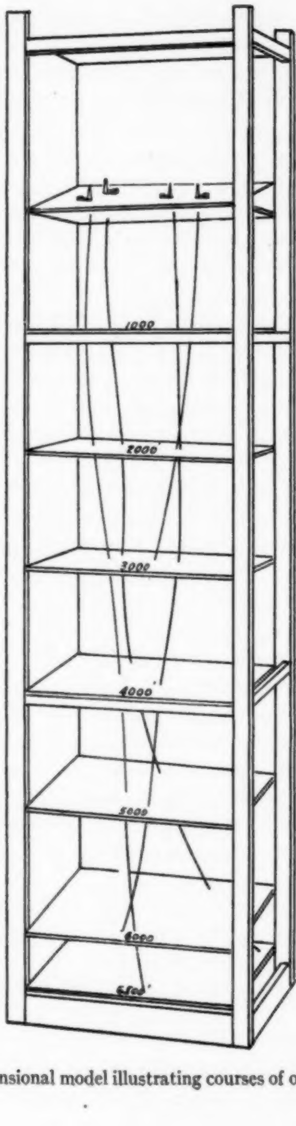


FIG. 1.—Three-dimensional model illustrating courses of oil-well drill holes. Depth shown in feet.

Many personal opinions were obtained, but much of the specific information desired was not on record.

The most prevalent factor seems to be the disposition of the bit to follow down the dip of the formations. This generalization must be qualified by the fact that probably 75 per cent of the surveys examined were made in the Long Beach field where the dips are steep. It also happens that most of the survey data examined related to wells whose production was unsatisfactory, and in most of such wells this condition is the result of their having migrated toward the edge of the field.

The most common opinion among operators as to the principal cause of deflection, aside from that already stated, is that too much pressure is applied to the drill stem, thereby causing it to bend. This factor commonly results from the desire for great speed in drilling.

Considerable thought was given to the suggestion that changes in the sizes of drill stems might be responsible for deflection. There is some evidence in support of this theory. In several wells changes in the courses of the holes were observed just below the points where strings of casing had been set. Since it is a common practice to change the size of drill stem after setting casing, these two factors are related.

There is, in addition, the fact that most strings of casing are cemented and that when the cement is drilled out the bit may find the path of least resistance beside the cement plug rather than through it, thus causing a deflection of the hole.

Another very probable cause of deflection is a marked change in the hardness of the formations penetrated. There appear to be more holes in which deflection is caused by changes from hard to soft formation than holes in which the reverse is true.

Changes of bits, or changes in the types of bits or core barrels, might also cause changes in direction, but sufficient data could not be obtained to reach a definite conclusion on this point.

It is obvious that the sidetracking of drill pipe or other obstacles in the holes will cause deflections.

### EFFECTS OF DEFLECTION

In a typical geologic cross section (Fig. 2) prepared to illustrate the effect of the migration of drill holes upon stratigraphic correlations, holes are represented as following divergent courses. One hole is approximately vertical; the second, starting from the same point, migrates up structure, and the third in the opposite direction. The dips of the strata are shown and correlative depths of the three wells indicated.

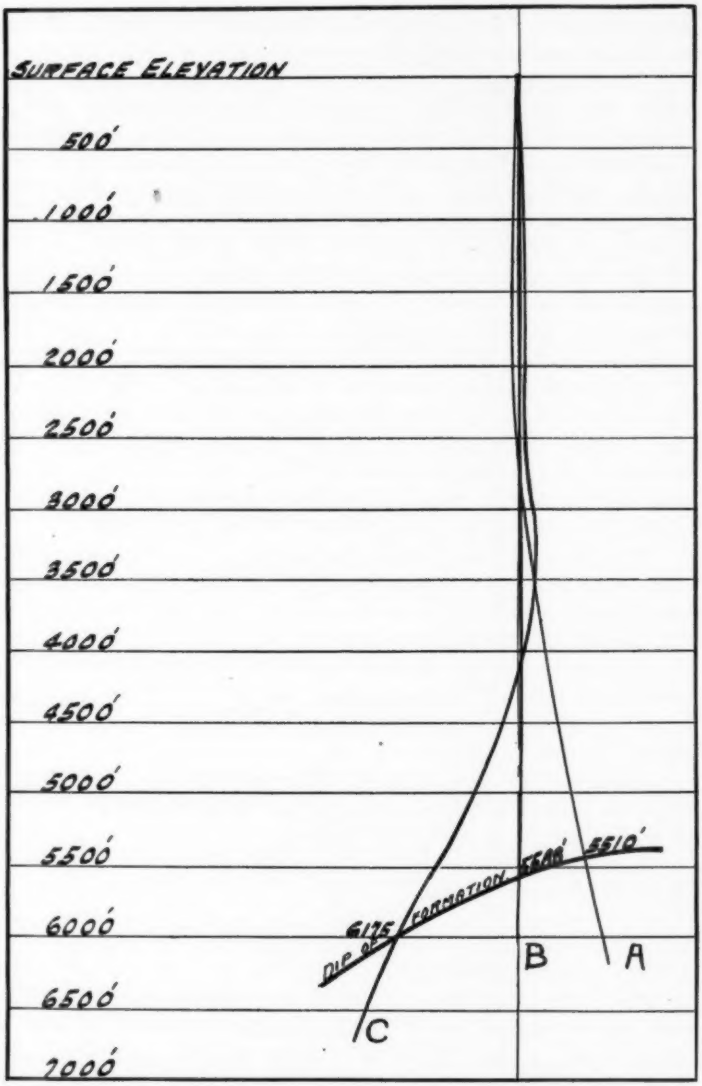


FIG. 2—Drawing to illustrate the effect of drift on the correlation of drill holes. A given formation is encountered at 6,175 feet by the same well drifting down the the dip which would have struck it at 5,510 feet if the hole had migrated up the dip, or at 5,588 feet if the hole had been vertical.

The inclination of the beds is approximately the same as in some parts of the Long Beach field, where most of the underground surveying has been done. On this drawing well *A* encountered the same strata at 5,510 feet that well *B* encountered at 5,588 feet and well *C* at 6,175 feet.

Until recently all underground correlations were based on the assumption that all drill holes were vertical. This drawing illustrates the errors which may result from such an assumption. These illustrations are not exceptional examples, but represent the common experience in the Long Beach field.

Many problems that could not heretofore be explained, now become understandable. For example, of two adjacent wells, one may be a producer of the first magnitude and the other may produce nothing but water, because one hole was deflected away from the oil-producing area into water-bearing formations, while the others, starting from similar locations at the surface, remained in the oil-producing area. Intercommunication between wells which are long distances apart on the surface can be explained in the same way.

It is also seen that the dip of the formations obtained in core samples may be seriously misinterpreted by lack of knowledge of the inclination of a hole at the point where the sample was taken. For example, a core sample taken in well *C*, previously mentioned, at a depth of 6,175 feet, might indicate a dip of 57° instead of the 30° dip which actually exists.

### POSSIBLE REMEDIES

To a large extent the probable causes of deflections of drill holes suggest their own remedies.

The dip of the formations as possibly causing deflection of the bit is not in the category of conditions which can be remedied, and there is no way of preventing changes in hardness of the formations, but these changes can be offset in part by changes in the types of bits used. Such changes in bits are, of course, commonly made for the purpose of increasing the speed of drilling.

The easiest and most promising preventive measure to apply is the application of less weight on the bit. If the drill pipe is suspended so as to keep it straight, it would seem that the resulting hole would of necessity be nearly vertical; but if the bit carries too much of the weight of the drill pipe, the latter is bound to be bent and deflection of the direction of the hole must result.

The use of reamers above the bit has been suggested as a means of keeping the bit steady.

The use of the largest practicable size of drill pipe should also aid in keeping the hole straight, because the larger sizes are more rigid than the smaller. The diameter of even the larger sizes is so infinitesimal compared with the length of the string that there is bound to be considerable flexibility in any case. This is well shown by the model, although, even there, the diameter of the copper wire is about ten times as great, proportionally, as that of the drill stem. To be comparable the wire should have a thickness of 0.005 inch.

Particular care should be taken in drilling out cement below the bottom of each string of casing.

No means suggest themselves for preventing deflections caused by obstacles in the hole, such as sidetracked drill pipe or casing.

However, where a survey has shown important deflections in the course of the hole, steps may be taken toward changing the direction by mechanical means. The two most common methods in use are (1) the cementing of the hole at the point where a change of direction is desired, and (2) the placing of a whipstock at that point.

This investigation did not reveal the existence of any agency which would result in a deflection in a predetermined direction.

As stated at the beginning, the knowledge obtained from underground surveys will probably have a revolutionary effect upon drilling practice. Much thought is being devoted to means for producing vertical holes. Probably improvements will soon be made in the type of drilling equipment, with this end in view.

# DEVELOPMENT AND RELATION OF OIL ACCUMULATION TO STRUCTURE IN THE SHIPROCK DISTRICT OF THE NAVAJO INDIAN RESERVATION, NEW MEXICO[1]

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## ABSTRACT

Residence of 14 months at Shiprock in 1923 and 1924, while representing the United States Bureau of Mines, and subsequent trips have afforded the writer opportunities to observe the results of development of the Navajo Reservation. The structures which were considered most favorable for oil accumulation yielded negative results, and the less favorable one was developed into a producing field.

The writer points out the possibility that circulating underground waters, in accordance with the hydraulic theory, have been responsible for the vagaries of accumulation, and some proof is offered. The suggestion is made that an intensive study of the Shiprock region would furnish additional evidence related to oil accumulation in that area.

## ACKNOWLEDGMENTS

The writer is indebted to R. S. Ellison, vice-president, Midwest Refining Company, and W. H. Ferguson, vice-president, Continental Oil Company, for permission to use the total production figures for the Hogback, Table Mesa, and Rattlesnake fields. Acknowledgment is also made to Fred E. Wood of the Midwest Refining Company for the use of Hogback water analyses.

The following persons also assisted the writer by supplying needed information: J. C. Nicklos, superintendent, and C. H. Erskine, assistant superintendent of the Continental Oil Company at the Rattlesnake field; L. G. Snow, associate petroleum engineer, United States Geological Survey at Shiprock; and Bruce M. Barnard, mayor of Shiprock.

## INTRODUCTION

The Shiprock district, in and adjacent to the Navajo Indian Reservation, which is situated in the northwestern corner of New Mexico, is one of the most interesting oil-producing districts in the United States. In this area three commercial oil fields lie within a few miles of one

[1]Manuscript received by the editor, November 1, 1928. Published by permission of the director, U. S. Bureau of Mines. (Not subject to copyright.)

[2]Supervising engineer, U. S. Bureau of Mines Research Office.

another, each located on a well-defined structure and producing a very high-gravity oil. The gravities of the oils range from 57° to 76° A.P.I. These producing fields are known as Rattlesnake, Hogback, and Table Mesa. Three other evident domes (Chimney Rock, Tocito, and Beautiful Mountain) are in the same district, but they have been proved nonproductive. A seventh structure, not so well defined, is Mancos Creek, approximately 20 miles north of the others, in Montezuma County, Colorado. Several shallow wells have been drilled there, but only small quantities of 36°-gravity shale oil were produced.

The oil fields and structures mentioned are within a radius of 28 miles from the village of Shiprock, where the San Juan Indian Agency and Bruce Bernard trading post are located. Figure 1 shows the location of the domes.

The purpose of the writer is to describe the geology, development, and peculiar characteristics of the several fields, giving particular attention to the factors that have influenced the accumulation of oil in the Shiprock district. He believes that there is a considerable amount of evidence that will help substantiate the hydraulic theory of accumulation of oil. This theory may account for the barrenness of some structures.

## HISTORY OF DEVELOPMENT

Impetus to geological exploration in the Shiprock district was given in 1922, when the Midwest Refining Company drilled a deep test in the Pennsylvanian to a depth of 4,588 feet on the McElmo (Colorado) structure, which is 42 miles north of Shiprock. A few barrels of oil with a gravity of 61° Bé., and a flow of gas of 4,000,000 cubic feet per day were obtained. This company and the Producers and Refiners Corporation, in the same year, developed three gas wells, each producing as much as 72,000,000 cubic feet daily on the Southern Ute dome, 24 miles northeast of Shiprock.

Several of the major oil companies sent geologists into the district as a result of these discoveries, and by the early part of 1922 several of the known geologic structures in the Shiprock district had been located and mapped in detail. The Midwest Refining Company applied to the Navajo Tribal Council and secured a lease on the Hogback structure, and the first well was spudded in on August 5, 1922. A 375-barrel flow of high-gravity oil was obtained in the Dakota sandstone and drilling was stopped at a depth of 796 feet on September 25, 1922.

This discovery was important and led to additional detailed geological field work throughout the entire San Juan basin. The Rattlesnake, Table Mesa, Tocito, and Beautiful Mountain structures were found to be worthy of oil tests, and so many requests for leases were

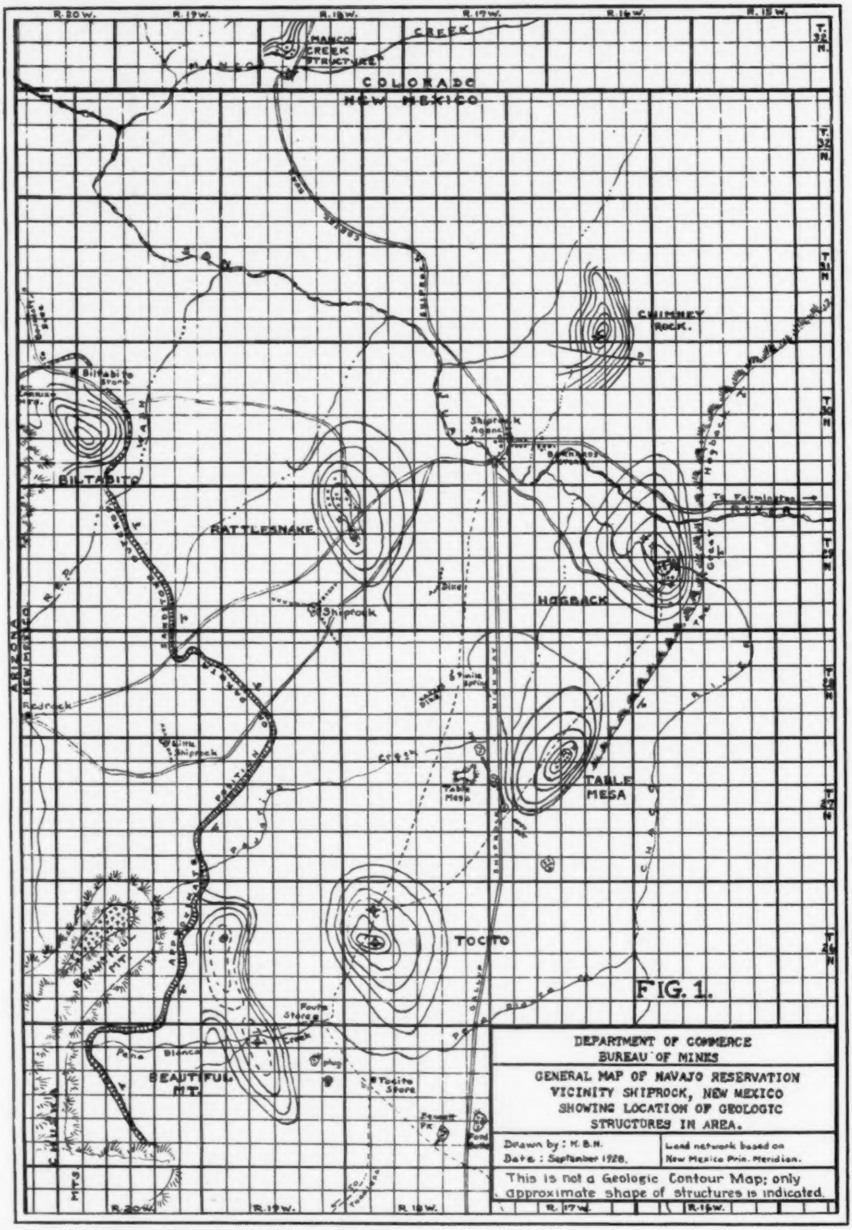


FIG. 1.—General map of Shiprock district, showing location of geologic structures. Width of area mapped, approximately 34 miles.

made that both the Navajo Tribal Council and the United States Indian Department decided upon a policy of auctioning the leases to the highest bidder.

Arrangements were made by H. J. Hagerman, commissioner to the Navajos, at Santa Fé, New Mexico, in October, 1923, and the four domes with several small tracts on the flanks of the Hogback structure were offered for sale. Nearly all of the tracts were sold, and by February, 1924, tests were being drilled on Rattlesnake by the Santa Fé Oil Company; on Table Mesa by A. E. Carlton, with the Producers and Refiners Corporation; on Tocito by the Gypsy Oil Company; and on Beautiful Mountain by the Navajo Oil Company. A discussion will be given later in this paper regarding the results obtained on each structure.

At a subsequent sale held at Santa Fé on June 23, 1926, a new structure, known as Chimney Rock, with Biltabito and several tracts at the edges of the producing fields, were offered. The Marland Oil Company was the successful bidder on the Chimney Rock structure and drilled a test well on it in the fall of 1926.

## GENERAL NOTES ON GEOLOGY

The entire district adjacent to Shiprock between the Great Hogback on the east and Red Wash near the Arizona-New Mexico state line comprises the western edge of the San Juan basin and is covered with Mancos shale (Upper Cretaceous). This shale is underlain by the Dakota sandstone, the objective oil-producing horizon of the district.

The regional dip of formations in the western part of the basin in general is toward the northeast, east, or south, ranging from 1° to 5°, except in the vicinity of the Great Hogback, where dips ranging from 14° to 33° may be found. The Great Hogback, at the eastern edge of the Navajo Treaty Reservation, is composed of the Mesa Verde formation, which is tilted and eroded to such an extent that it protrudes above the surrounding plain of softer Mancos shale.

The structural features of the basin are probably due to local uplifts caused by the Carrizo Mountains on the west, a group of volcanic intrusions of considerable importance, and the La Plata Mountains on the northeast. Ute Mountain, a large igneous plug southwest of Cortez, Colorado, also may have had considerable geologic influence. In fact, the whole highland-mountain area along the Arizona and New Mexico border, of which the Carrizos and Ute Peak are the most prominent features, is very probably the result of intrusions, which are exposed at different places along the range. The Chuska Mountains immediately south of the Carrizos are capped by sediments of the Eocene.

An important geologic feature of the Shiprock basin is the existence of numerous volcanic intrusions and plugs. The rock, Shiprock itself, which is about 4 miles southwest of the Rattlesnake structure, is a tall, intrusive plug rising to an elevation of about 1,800 feet above the surrounding plain. Farther south, not far from the Tocito and Table Mesa structures, are similar plugs known as the Table Mesa Plug, Bennett Peak, and Fort Buttes.

There is evidence also that a second stage or period of volcanic action came into existence in post-Mancos time. Several of the plugs have dikes, radiating from the central core; at Shiprock there are three dikes, each almost 2 miles in length and extending at angles of approximately 120° from one another. The dikes are of igneous material different from the plugs, and the adjacent shales are considerably metamorphosed and altered. There is additional evidence of post-Cretaceous disturbance in one of the dikes extending southeast of the Table Mesa plug. In this dike there is much intrusive material and breccia which has issued from the bedding planes of a sandy shale and sandstone horizon within the Mancos shale.

Post-Cretaceous activity must certainly have involved folding of the Carrizo and Chuska Mountain group, because all of the Cretaceous deposits are affected in the folding and, with older sediments as low as the Jurassic, are exposed on the flanks of the mountains. The same condition applies to Ute Mountain on the north.

All the domes, except one, in the Shiprock district, have the Mancos shale at the surface, and on the Hogback, Rattlesnake, Tocito, and Beautiful Mountain structures a sandstone is exposed within the Mancos. It is called the Tocito sandstone because of its type exposure on the Tocito structure.

## DEVELOPMENT

On the six domes within the Navajo Reservation 54 wells have been drilled, exclusive of several on the Boundary Butte structure in southeastern Utah located on Executive Order parts of the reservation. The number of wells (including water wells and dry holes) is as follows:

| *Field or Structure* | *Number of Wells* |
|---|---|
| 1. Rattlesnake | 23 |
| 2. Hogback | 15 |
| 3. Table Mesa | 12 |
| 4. Tocito | 2 |
| 5. Beautiful Mountain | 1 |
| 6. Chimney Rock | 1 |
| Total | 54 |

In addition, 12 wells have been drilled on the Mancos Creek structure.

The first three domes which have been developed into commercial oil fields deserve the most attention. As the Hogback and Rattlesnake fields have been described in detail in previous articles,[1] a detailed discussion will not be given in this paper. However, mention will be made of the peculiarities of development in each field, and general information will be given regarding subsurface features which might have a direct bearing on the general relation between oil accumulation and structure.

### HOGBACK FIELD

The Hogback dome, 10 miles southeast of Shiprock village, contains approximately 20,000 acres within its lowest closing contour. Of this area, approximately 267 acres have been proved to be productive.

The apex of the structure is covered by the Tocito sandstone, a prominent sandstone member of the Mancos shale, except where it has been eroded away by Dry Chaco River. The productive sand is the Dakota, at an average depth of approximately 725 feet. Up to the present, drilling has not proceeded below the base of the Dakota, except in the well of the Santa Fé Mutual Company. This well was drilled with the Shinarump conglomerate horizon as an objective, but after a depth of 1,965 feet had been reached it was abandoned because of a difficult fishing job.

To date, 15 wells have been drilled in the field—12 by the Midwest Refining Company, 2 by R. D. Compton, and 1 by the Santa Fé Mutual Company. Seven Midwest wells are producing oil; the other 5 wells were either water wells or they produced large quantities of water with some oil. Table I gives a summary of the drilling.

*Drilling practice in Hogback field.*—The character of the formations in the Hogback field is such that no difficulty in drilling is experienced. After the drill penetrates the Tocito sandstone on the surface, nothing but a compact shale (Mancos) is encountered until the Dakota sandstone is reached. There are, however, a few sandy horizons within the Mancos and also a thin limestone bed which is the equivalent of the Greenhorn limestone of Colorado. This bed is not logged in all the wells, however. All of the beds mentioned "hold up" well while being drilled and almost no difficulty from caving is experienced.

The practice is to cement about three joints of conductor pipe through the Tocito sandstone, if possible, with 10 sacks of cement to

[1] K. B. Nowels, "Navajo Reservation Development," *Oil and Gas Journal* (Oct 1, 1925).

"Oil Production in Rattlesnake Field," *Oil and Gas Journal* (June 7, 1928).

TABLE I

SUMMARY OF DRILLING FOR HOGBACK FIELD

| *Well No.* | *Location Sec.-T.-R.* | *Surface Elevation in Feet* | *Depth to Top of Sand in Feet* | *T tal Depth in Feet* | *Production in Barrels* |
|---|---|---|---|---|---|
| | | | MIDWEST REFINING COMPANY | | |
| 1 | NE. ¼ 19-29-16 | 5,133 | 722 | 988 | 375 oil cemented off, and made a test well. Using as water well |
| 2 | NW. ¼ 19-29-16 | 5,132 | 785 | 795 | 1,276 first 24 hours |
| 3 | NW. ¼ 20-29-16 | 5,061 | 1,003 | 1,225 | 3,000 sulphur water in Dakota. Plugged and abandoned |
| 4 | NW. ¼ 19-29-16 | 5,132 | 837 | 842 | 1,200 sulphur water when drilled; now capable of making 5-10 oil |
| 5 | SE. ¼ 19-29-16 | 5,125 | 760 | 763 | Estimated 1,200 oil when drilled; now producing little water |
| 6 | SE. ¼ 19-29-16 | 5,126 | 771 | 783 | Oil and water; amount not determined; estimated 60 oil, 300 water; plugged and abandoned |
| 7 | NE. ¼ 19-29-16 | 5,003 | 647 | 657 | 1,200 oil |
| 8 | SE. ¼ 18-29-16 | 5,029 | 679 | 684 | 500 oil. Sand just touched. Would probably be as good as No. 7 |
| 9 | NE. ¼ 19-29-16 | 5,004 | 633 | 647 | 212 oil |
| 10 | NE. ¼ 19-29-16 | 5,008 | 650 | 664 | 20 oil for two weeks. Small amount water. Plugged |
| 11 | NE. ¼ 19-29-16 | 5,035 | 668 | 677 | 110 oil |
| 12 | NE. ¼ 19-29-16 | 5,134 | 774 | 776 | 656 oil. Small amount water |
| | | | R. D. COMPTON | | |
| 1 | NE. ¼ 30-29-16 | 5,125 | 892 | 925 | 500 water |
| 2 | SE. ¼ 13-29-17 | 5,081 | 776 | 799 | Sulphur water. Now plugged and abandoned |
| | | | SANTA FÉ MUTUAL COMPANY | | |
| 1 | NE. ¼ 13-29-17 | 5,090 | 823 | 1,965 | Big flow sulphur water in Dakota. Abandoned |

exclude surface water and any seepage that may be found in the Tocito. Ten-inch or even 8¼-inch conductor pipe can be set and a well finished with a string of 6⅝- or 5³⁄₁₆-inch pipe as the oil string.

Some trouble has been experienced in finishing some of the wells because of the character of the Dakota sandstone and the impossibility of forecasting the conditions to be encountered. In one part of the field, a dry stray sand found about 12 feet above the top of the main Dakota oil-bearing sand during the initial drilling, was thought to be a reliable marker, and it had been the practice to drill through the sand a few inches, set casing, and cement before drilling ahead through a 3- to 7-foot shale break on top of the oil sand. The dry, stray sand and the shale

break have been found in wells Nos. 2, 4, and 7, but in the other wells they are missing.

Well No. 5 was the first to be drilled where the dry sand was missing; as the well was located higher on the subsurface structure than was intended, oil was encountered and a flow obtained before drilling could be stopped. It is the highest well, structurally, that has been drilled. Figure 2 shows a subsurface contour map based on well logs.

In well No. 6, which is a short distance southeast of No. 5, no dry sand was found separated from the oil sand by a shale break, as in No. 2. From 10 to 12 feet of dry sand was encountered, however, but the tools went immediately through a thin shell into oil and water. This was unexpected, as the well is higher structurally than No. 2, which is free from water and one of the best wells in the field. It is believed that the oil-bearing sand has almost pinched out in No. 6 and that only a few inches of sand remain close to the top of the shell which separates the dry sand from the water. The few inches of sand could supply the amount of oil that was found. Well No. 6 has been abandoned, and it is thought that the water encountered was coming from sand below the shell.

*Top water.*—As far as development has progressed to date there have been two actual discoveries of top water in the field. Top water was encountered in wells No. 9 and No. 10, and its presence was suggested in the initial drilling of well No. 1 when an attempt was made to cement off what was thought to be bottom water. Well No. 1 was finally cemented successfully, and all evidence points to the presence of top water. As a precautionary measure a water test is made after every cementing job before a well is drilled in.

Well No. 3, located 300 feet down structure from the apex on the east flank of the dome, after encountering some water in the Tocito sandstone, produced about 3,000 barrels of sulphur water a day in the Dakota. The well was later plugged and abandoned to prevent any migration of water to other parts of the field through sandy shale and sandstone horizons.

*Lenticular sand conditions.*—Drilling on Hogback has shown that lenticular sand conditions are an important factor in the development of the Hogback field. This statement applies to any field where the Dakota is the objective sandstone. Figure 3 shows the present interpretation of subsurface conditions of the Hogback field.

*Pressures.*—The wells drilled in Hogback had an average closed-in pressure of approximately 182 pounds per square inch in 1925. There

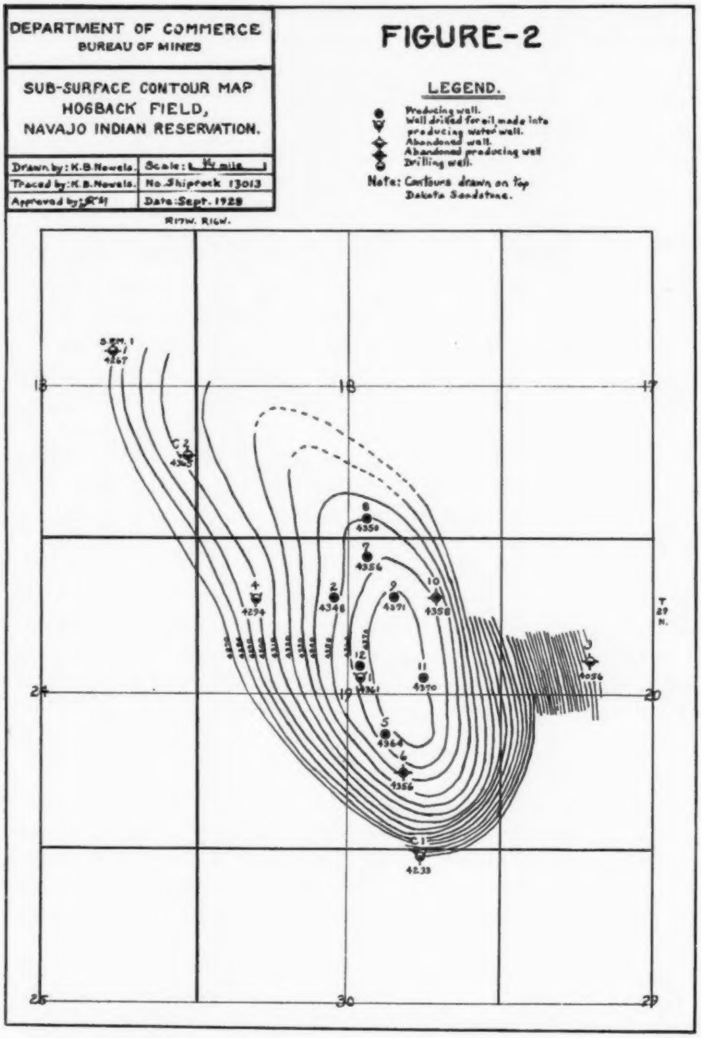


Fig. 2.—Subsurface geologic contour map of Hogback field.

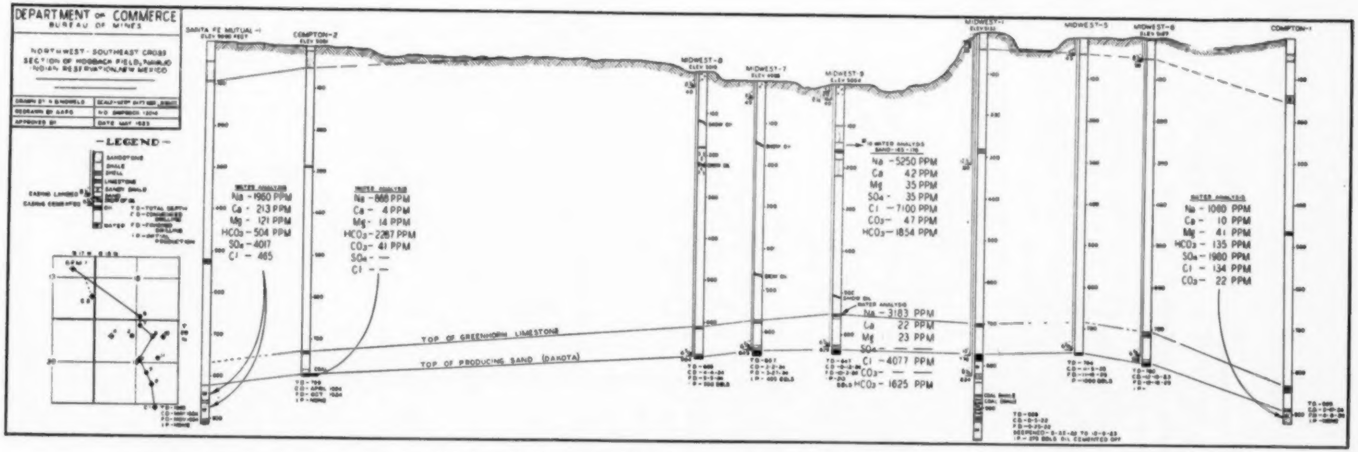


FIG. 3.—Northwest-southeast cross section of Hogback field.

is no gas present, and the wells flow because of water pressure back of the oil; consequently, the wells are not of the gusher type. The oil comes to the surface and gently flows over the top of the casing.

If some of the wells in Hogback are allowed to flow unrestrictedly they make small quantities of water, a condition which may be expected in fields of this type. As a result, it is necessary to hold certain back pressures on the wells to eliminate the water. The pressures held are approximately 100 pounds per square inch.

The Hogback field, up to August 1, 1928, had produced 799,469 barrels of oil of an approximate average gravity of 63° A.P.I. This gives a recovery, up to that date, of 2,994 barrels per acre, on a basis of 267 productive acres.

An interesting feature in connection with Hogback No. 4 well is worthy of mention. This well was drilled in October, 1923, and the top of the Dakota was reached at a depth of 837 feet after passing through the 7-foot dry sand from 823 to 830 feet. The 8¼-inch casing was cemented in the shale between the two sands. Only 5 feet of the main part of the Dakota was penetrated, and drilling was stopped on account of striking a 1,200-barrel flow of bitter sulphur water from a depth of 827 to 842 feet. The well is very low structurally, and no sign of oil was found. This well was allowed to flow unrestrictedly for several months. In December, 1923, a small amount of oil appeared, rising in small globules about the size of a pea and breaking on the surface of the water as it flowed over the top of the casing. The amount of oil gradually increased until it is estimated that the well's daily oil production varied from 5 to 10 barrels. The well has since been closed in and is no longer used as a water well.

### RATTLESNAKE FIELD

In February, 1924, the second discovery of oil in the Shiprock region was made on the Rattlesnake structure, 8 miles southwest of Shiprock and 13 miles west of the Hogback field. This dome contains approximately 10,000 acres, within the lowest closing contour of which approximately 900 acres have been proved productive.

Although the lease was originally purchased by S. C. Munoz of New York City, the Continental Oil Company of Denver later acquired an interest in the field and now operates it.

The producing sand is the Dakota, which has been found at depths ranging from 700 to 900 feet. Above the Dakota lies the Mancos shale. Because there are no water sands above the Dakota, it is possible to set and cement a surface string of casing and then to drill an open hole down

to the producing sand before running the oil string. Figure 4 gives a subsurface contour map of the field and Figure 5 shows a cross section of it.

The Dakota sand is more lenticular at Rattlesnake than at Hogback, and in some wells it exists in two or three benches, any one of which may carry oil or water. The benches are separated by shale breaks or hard shells. In two or three wells the top member carried small amounts of oil, the second bench was full of water, and the third carried the flowing oil production. Altogether, 23 wells have been drilled, although 5 have been abandoned as edge wells because they carried too little oil to justify operating them. Two of these 5 were developed later into water wells to supply the needs of the camp and field. Up to August 1, 1928, the Rattlesnake field had produced 855,064 barrels of oil.

The north end of the field has been the most extensively drilled (Fig. 4), but well No. 22 has proved the southern end of the anticline to be oil-producing, and good wells are anticipated. The initial production of the wells has varied from 30 to 1,500 barrels a day. Well No. 5, for example, was originally drilled to a depth of 758 feet in September, 1924, and its initial production was 300 barrels of oil. When the lower bench of the Dakota was found to be oil-carrying, the well was deepened to 839 feet in May and June, 1926, and started flowing at the rate of 1,500 barrels per day. In July, 1927, the well was capable of producing 420 barrels of oil and 285,000 cubic feet of gas per day. Almost all of the producing wells have since been deepened and an increase in production has resulted.

At present only two of the wells are allowed to flow. Most of the others are pumped by band-wheel power and jack. Nearly all of these wells would flow, but as some of them produce small amounts of water, the method of operation is to lift the water off the sand to prevent its accumulating and "killing" the well.

Table II gives a summary of the drilling done in Rattlesnake.

In August, 1924, the Midwest Refining Company completed a 3-inch welded pipe line from their Hogback field to Farmington, New Mexico, from which point they now ship oil by tank cars to the Utah Oil and Refining Company at Salt Lake City. By laying a 2-inch line, approximately 13 miles in length, between the Rattlesnake and Hogback fields, an outlet for Rattlesnake crude also was provided. This lateral was built in the early part of 1925. The Continental Oil Company built a 750-barrel refinery at Farmington to refine the oil shipped by them through the Midwest line. This small refinery supplies most of the gasoline used in its immediate area.

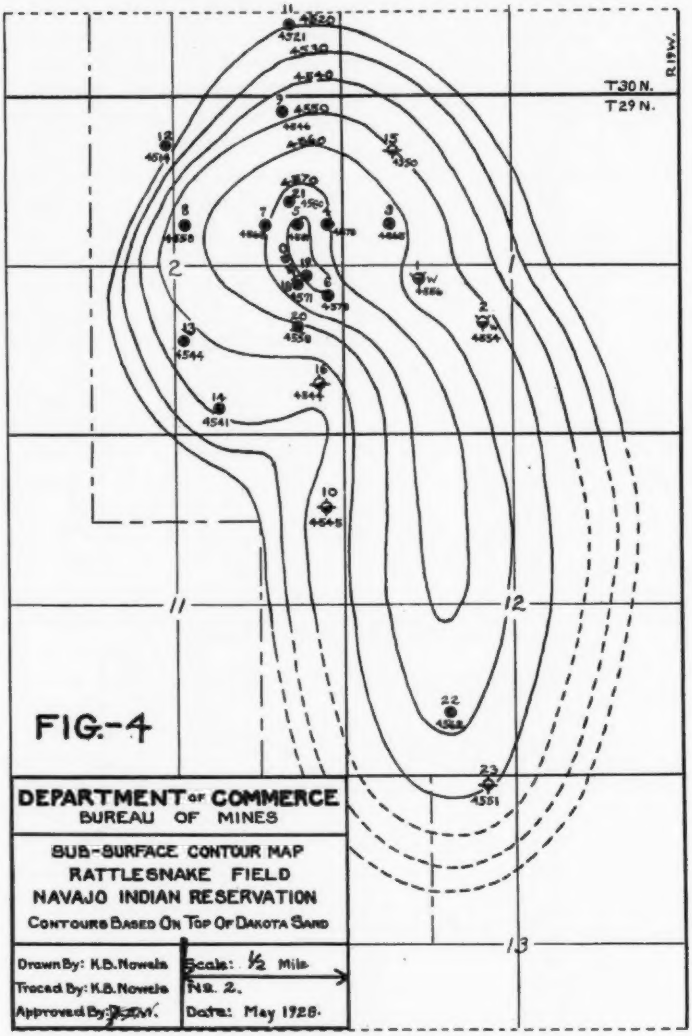


FIG. 4.—Subsurface geologic contour map of Rattlesnake field.

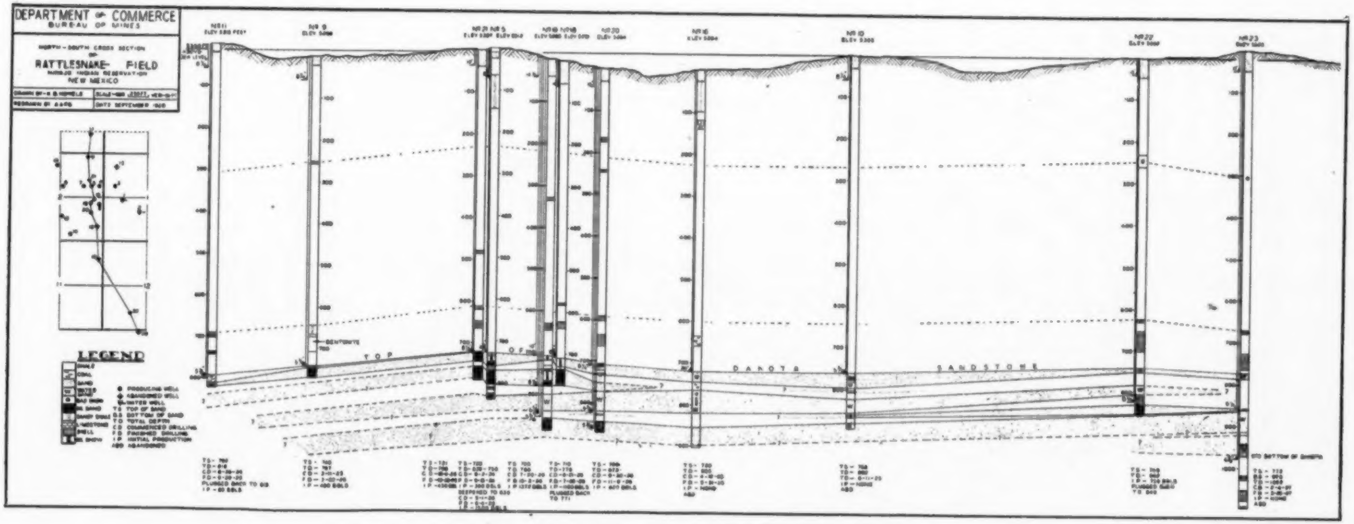


FIG. 5.—North-south cross section of Rattlesnake field.

Although the oil was known to be of extremely high gravity, approximately 74° A.P.I., as soon as the initial wells were drilled in, no difficulty was anticipated in handling it through the ordinary pipe line.

Difficulties were experienced, however, almost as soon as the shipment of Rattlesnake crude was started through the line. The Shiprock region is arid, and in the summer months atmospheric and ground surface temperatures are high. Because of its extremely high gravity and volatility, the oil, upon entering the warm pipe line, immediately begins to vaporize to such an extent that to pump it or run it by gravity through the line is almost impossible. Gas from the oil collects in pockets at high points, and the line becomes gas-locked. Even in the field, it is impossible effectively to transfer oil by gravity from a 500-barrel tank situated on the side of a hill to other tanks 700 feet distant and 30 feet lower in elevation. After sundown, in the cooler evening hours, the movement of oil begins, and the run can be completed in a short time without difficulty.

*Properties of Rattlesnake crude and its natural gas.*—A statement of the characteristics of the oil will give a better understanding of its peculiar nature and behavior. In July, 1927, while some production tests were being made in the field, a sample of fresh oil from well No. 21 was drained from the oil-gas separator, which was under pressure of 10 pounds, and a gravity reading was taken with a hydrometer. Although the atmospheric temperature at the time was about 80° F., the oil sample had a temperature of 32° F., and was boiling. At this temperature, the A.P.I. gravity was 69.5°. After corrections had been made for a temperature of 60° F., the gravity was approximately 73.4°. In another test during March, 1928, a sample from well No. 22 taken directly from the casinghead had a gravity of 70.2° A.P.I. at 35° F., or of 73.7° A.P.I. at 60° F. The oil as it comes from the wells is light amber in color and has the appearance of apple-cider vinegar.

A special thermometer was placed in the flow line at the top of the wellhead of No. 5 during tests in March, 1928. The average temperature of the flowing oil and gas was 48° F. During brief periods of only 4 or 5 seconds when the well was flowing gas with almost no oil, the temperature dropped to 42° F.

Aluminum-painted vapor-proof receiving tanks are used throughout the field, but even in these containers there is an unavoidable loss of unstable volatile fractions from the oil. The flow lines, oil-gas separators, and tanks up to the height of the contained oil are always covered with frost and moisture, even in the summer time.

## TABLE II

SUMMARY OF DRILLING FOR RATTLESNAKE FIELD

| *Well No.* | *Location Sec.-T.-R.* | *Surface Elevation in Feet* | *Depth to Top of Sand in Feet* | *Total Depth in Feet* | *Oil Production in Barrels* |
|---|---|---|---|---|---|
| 1 | SW. ¼ 1-29-19 | 5,377 | 821 | 2,013 | Small amount oil. Later deepened for water well |
| 2 | SW. ¼ 1-29-19 | 5,364 | 810 | 1,430 | Water in Dakota. Using as water well |
| 3 | NW. ¼ 1-29-19 | 5,376 | 811 | 826 | Initial, 30 |
| 4 | NE. ¼ 2-29-19 | 5,355 | 785 | 961 | Initial, 100. Later deepened from 808 feet to 961 feet. Production, 46 |
| 5 | NE. ¼ 2-29-19 | 5,312 | 731 | 839 | Initial, 300. Deepened from 758 feet to 839 feet. Increased to 1,500 |
| 6 | SE. ¼ 2-29-19 | 5,303 | 725 | 788 | Initial, 25. Originally drilled to 752 feet. Deepened to 788 feet. Production 80 |
| 7 | NE. ¼ 2-29-19 | 5,283 | 715 | 797 | Initial, 805. Deepened from 760 feet to 797 feet. Increased to 500 |
| 8 | NE. ¼ 2-29-19 | 5,240 | 682 | 727 | Estimated, 100 |
| 9 | NE. ¼ 2-29-19 | 5,286 | 740 | 767 | Initial, 480 |
| 10 | NE. ¼ 11-29-19 | 5,303 | 758 | 892 | Small amount oil. Abandoned Water |
| 11 | SE. ¼ 35-30-19 | 5,313 | 792 | 818 | Initial, 80 |
| 12 | NW. ¼ 2-29-19 | 5,216 | 702 | 736 | Initial, 125 |
| 13 | SE. ¼ 2-29-19 | 5,216 | 672 | 703 | Initial, 50 |
| 14 | SE. ¼ 2-29-19 | 5,244 | 703 | 860 | Initial, 110 |
| 15 | NW. ¼ 1-29-19 | ? | 815 | 954 | Plugged and abandoned. Showing oil and gas. Water |
| 16 | SE. ¼ 2-29-19 | 5,264 | 720 | 905 | Commenced as deep test. Abandoned when Dakota failed to produce |
| 17 | NE. ¼ 2-29-19 | 5,294 | 710 | Drilling | Good production in Dakota. Drilling as Pennsylvanian test |
| 18 | SE. ¼ 2-29-19 | 5,281 | 710 | 711 | 1,100. Show of water |
| 19 | SE. ¼ 2-29-19 | 5,285 | 708 | 886 | Initial, 1,200 to 1,300 |
| 20 | SE. ¼ 2-29-19 | 5,264 | 706 | 872 | Initial, 820 |
| 21 | NE. ¼ 2-29-19 | 5,307 | 721 | 788 | Initial, 450 from first and second sands |
| 22 | SW. ¼ 12-29-19 | 5,302 | 740 | 849 | Initial, 739 |
| 23 | NW. ¼ 13-29-19 | 5,323 | 772 | 1,092 | Drilled into McElmo. Water in Dakota with showing of oil. Water in McElmo |

To gauge the amount of Rattlesnake crude in a tank by means of the ordinary wooden gauge pole is almost impossible, especially if the oil is fresh from the well. When the pole (which is ordinarily of atmospheric temperature) is lowered into the tank, the entire tank of oil starts to boil, and the surface of the fluid is in such violent motion that an accurate gauge reading can not be made. In order to use a gauge pole satisfactorily in fresh oil, it is necessary to leave it immersed in the tank until thoroughly chilled.

Most of the tank gauging is done with steel tape and plumb-bob, as there is less body to the tape and it chills very quickly. A piece of chalk or clod of dirt must be used to dust the tape approximately where the oil surface in the tank will strike it, in order that a clear reading may be secured. The oil is so light and of such low viscosity that it will not leave a mark without the use of chalk or dirt.

In the summer the fresh oil in a tank is in constant agitation because the atmospheric temperature throughout a 24-hour period is ordinarily higher than the initial boiling point of the fresh oil.

Some idea of the unstable nature of the oil may be gained from the following data supplied by the Continental Oil Company:

Three samples of fresh oil were taken from the Lorraine separator under 50 pounds' pressure at 8:00 A. M., April 14, 1926. Engler gasoline distillations were made after sample No. 1 had been left in an open can for two hours, and samples No. 2 and No. 3 had weathered slightly over 24 hours. Sample No. 2 was set inside the Rattlesnake warehouse annex, where it was away from air drafts and direct sunlight. Sample No. 3 was set on the ground by one of the oil-receiving tanks, where it would be exposed to as little wind and sunshine as outside conditions would permit. With sample No. 1, it was impossible to make the distillation at the time the sample was taken, and it was furthermore impossible to hold any sample in an ordinary container at room temperature without weathering considerably. In the distillations standard charges of 100 cc. were used.

TABLE III

Distillation Data of Rattlesnake Crude

| *When First Drawn* | *Sample No. 1* | *Sample No. 2* | *Sample No. 3* |
|---|---|---|---|
| *Gravity at 60° F.*<br>*Temperature* | *76.3°*<br>*8° F.* | *76.3°*<br>*8° F.* | *76.3°*<br>*8° F.* |
| When distillation was made | Apr. 14, 1926<br>10:00 A. M. | Apr. 15, 1926<br>10:30 A. M. | Apr. 15, 1926<br>12:00 noon |
| Gravity | 69.3° A.P.I. | 63.5° A.P.I. | 60.0° A.P.I. |
| Oil temperature | 52° F. | 70° F. | 69° F. |
| Room temperature | 61-65° F. | 70° F. | 70° F. |
| Condenser temperature | 34° F. | 34° F. | 34° F. |
| Initial boiling point | 70° F. | 82° F. | 96° F. |
| Maximum recovery | 79.5 cc. at 62° F. | 93 cc. at 68° F. | 93.5 cc. at 68° F. |
| Distillate gravity | 65.1° A.P.I. | 64.5° A.P.I. | 61.3° A.P.I. |
| Residue | 4 per cent | 4 per cent | 4 per cent |
| Loss | 16.5 per cent | 3 per cent | 3 per cent |

Table III shows that the initial boiling point of the oil in Sample No. 1 was 70° F. two hours after it was taken from the well. In 24.5

hours the initial boiling point had increased to 82° F., and in 28 hours it was 96° F. Fresh from the well, however, the boiling point of the oil is approximately 32° F. These data are sufficient to indicate the rapid rate of weathering.

The crude direct from the well is so volatile that it has to be stabilized by a special process before it can be handled in a pipe line.

An Engler distillation test of crude which had been shipped through the 33 miles of pipe line from Rattlesnake to the refinery at Farmington on February 14, 1928, shows 62.5° A.P.I. at 47° F., or 64.1° A.P.I. at 60° F. The results are shown in Table IV.

TABLE IV

ENGLER DISTILLATION TEST OF CRUDE, RATTLESNAKE FIELD

| | |
|---|---|
| *Temperatures* | |
| Crude | 47° F. |
| Room | 66° F. to 68° F. |
| Condenser | 30° F. to 40° F. |
| Receiving bath | 56° F. to 60° F. |
| *Results of Distillation* | |
| Initial boiling point | 70° F. |
| 10 per cent | 120° F. |
| 20 per cent | 149° F. |
| 30 per cent | 179° F. |
| 40 per cent | 211° F. |
| 50 per cent | 245° F. |
| 60 per cent | 284° F. |
| 70 per cent | 350° F. |
| 80 per cent | 447° F. |
| 87.2 per cent | 566° F. |
| End point | 566° F. |
| Overhead recovery | 87.2 per cent |
| Residue | 3.8 per cent |
| Loss | 9.0 per cent |
| | 100.0 per cent |

*Gas analysis.*—During field work in July, 1927, the writer sent a sample of the casinghead gas from well No. 21 to the U. S. Bureau of Mines helium plant at Fort Worth, Texas, for fractional distillation and analysis. The sample was taken from a Lorraine separator under pressure of approximately 10 pounds. The analysis (Table V) shows the casinghead gas to consist of 61.27 per cent propane, butane, and higher hydrocarbons.

*Reservoir pressure and temperature.*—In the Rattlesnake field the "rock" pressure, or reservoir pressure, as determined by a special study during March, 1928, is approximately 270 to 280 pounds per square

TABLE V

ANALYSIS OF CASINGHEAD GAS, RATTLESNAKE FIELD

| | *Per Cent* |
|---|---|
| Carbon dioxide | 0.00 |
| Oxygen | 0.18 |
| Nitrogen | 1.14 |
| Methane | 9.83 |
| Ethane | 27.58 |
| Propane | 41.57 |
| Butane plus | 19.70 |
| | 100.00 |

inch. At the time this study was made, a maximum thermometer was lowered in a special "pressure bomb" to the bottom of well No. 5, which is 826 feet deep. During each of several runs the "bomb" was left at the bottom for 24 hours or longer. Each time the thermometer registered 75° F.

Under conditions of pressure and temperature which now exist in the wells of the Rattlesnake field, a fairly large part of the casinghead gas accompanying the oil is in a liquid state in the producing sand. A complete discussion of the properties and behavior of the gas found at Rattlesnake is given in the June 7, 1928, issue of the *Oil and Gas Journal.* The butane (19.70 per cent of casinghead gas) is shown to remain in the liquid state in the producing sand as long as the reservoir pressure is 152.2 pounds or more, assuming that the composition of the gas does not change.

Because of the existing underground conditions, some of the butane even reaches the surface in liquid form with the oil. The presence of liquid butane which, upon reaching the surface, changes over into vapor or gaseous form, accounts for the boiling of the oil at atmospheric temperature and for the difficulty in handling the oil.

The wells of this field, when flowing wide open, have a pressure at the casinghead varying from 20 to 30 pounds. The refrigeration effect produced by the expansion of gas in transit up the casing, and the progressive vaporization of the butane, is sufficient to hold the oil at a temperature below that necessary for the butane to liquefy at atmospheric pressure. At a pressure of 14.7 pounds per square inch, butane liquefies at 34° F. At an atmospheric pressure of 12.3 pounds per square inch, which exists at Rattlesnake, the liquefaction temperature or boiling point would be slightly lower—probably near 32° or 33°. These figures correspond with observations made in the field.

The volume of butane vapors which weather off from the receiving tanks is not known, but must be large, in view of the fact that in the three oil samples previously mentioned, sample No. 1 weathered from

a gravity of 76.3° - 69.3° A.P.I. in two hours, and to 63.5° in 26½ hours. Most of the weathering loss probably is due to vaporization of the butane content.

### TABLE MESA FIELD

The Table Mesa field, so named from the flat mesa, or erosional remnant of Point Lookout sandstone adjacent to it on the southwest, is an almost symmetrical anticlinal fold whose axis trends northeast and southwest. It has a reported closure of about 150 feet, but there is a structural difference of only about 15 feet from the present water line to the apex of the structure.

The mapping of this structure geologically was very difficult, because there were few outcrops upon which to base a plane-table survey. The Tocito sandstone, which is exposed on most of the other structures, lies 455 feet below the surface at Table Mesa, and geological work had to be based on thin, ferruginous "stringers" in the Mancos shale.

A test well was drilled by the Producers and Refiners Corporation for the A. E. Carlton interests about the same time that the first wells were drilled on the Rattlesnake structure. A flow of 1,500 barrels of soft, fresh water was encountered in the Tocito sandstone, and nearly every sandstone below that point carried water. The top of the Dakota, containing a considerable amount of sulphur water, was found at 1,405 feet. This well was drilled to a depth of 3,010 feet into the Navajo sandstone without securing production and was sold to the Indian Office as a water well.

In the early part of 1925 the Continental Oil Company was interested in the tract, and sent their geologists to make an investigation. During the month of May, 1925, their detailed work showed that an error had been made and that the axis of the structure was about 1,900 feet east of the test well. The Continental Oil Company therefore drilled a well on the new location, and on September 1, 1925, obtained a 325-barrel flow of high-gravity oil in the Dakota at 1,317 feet.

The Table Mesa field is small, and all of the wells now produce water with the oil. When the wells were first drilled, the closed-in casinghead pressure varied between 110 and 140 pounds, although the pressure is now almost zero, and the wells have to be pumped. The field is similar to Hogback in that no gas occurs with the oil and the wells are under hydrostatic-pressure control.

The oil is of high gravity, 57° - 58° A.P.I., and is a few degrees heavier than that of Hogback crude. Up to August 1, 1928, the Table Mesa field had produced 148,976 barrels of oil.

Exclusive of the original water well, 11 wells have been drilled in the Table Mesa field, 5 of which were abandoned and plugged on account of water. The summary of drilling is given in Table VI.

The oil-producing bench of the Dakota is thin in the Table Mesa field, ranging from 2 to 7 feet in thickness. Two of the wells were deepened in order to test the entire Dakota series, but no production was found. The field produces a considerable amount of water, which

TABLE VI

SUMMARY OF DRILLING FOR TABLE MESA FIELD

| *Well No.* | *Location Sec.-T.-R.* | *Surface Elevation in Feet* | *Depth to Top of Sand in Feet* | *Total Depth in Feet* | *Oil Production in Barrels* |
|---|---|---|---|---|---|
| | | | PRODUCERS AND REFINERS—CARLTON | | |
| 1 | NW. ¼ SW. ¼ 3-27-17 | 5,383 | 1,405 | 2,010 | Flowing water in every sand. Plugged and abandoned |
| | | | CONTINENTAL—CARLTON | | |
| 1 | SE. ¼ SW. ¼ 3-27-17 | 5,337 | 1,317 | ? | Initial production 325, 58° gravity |
| 2 | SW. ¼ 3-27-17 | 5,338 | 1,314 | 1,322 | 336 |
| 3 | NE. ¼ SW. ¼ 3-27-17 | 5,340 | 1,328 | 1,334 | 225 |
| 4 | SE. ¼ 3-27-17 | 5,324 | 1,318 | 1,325 | Water. Plugged to 1,320 feet. Water not shut off. Well making 9, with some water |
| 5 | SW. ¼ 3-27-17 | 5,355 | 1,358 | 1,361½ | Water in bottom plugged off. Production 75 |
| 6 | NW. ¼ 10-27-17 | 5,314 | 1,322 | 1,333 | Water. Plugged and abandoned |
| 7 | NW. ¼ 10-27-17 | 5,341 | 1,346 | 1,364 | Water. Plugged and abandoned |
| 8 | NE. ¼ SW. ¼ 3-27-17 | 5,355 | ... | ... | Crooked hole. Abandoned |
| 8A | NE. ¼ SW. ¼ 3-27-17 | 5,345 | 1,341 | 1,344½ | Initial, 52 fluid, 60 per cent oil. Plugged back to 1,342 feet. Pumped 16 oil and 10 water in 12 hours. Deepened later as test to 1,480 feet. Made 10 oil in 2 feet of sand at 1,400 feet. Plugged back to 1,444 feet. Made 10 on test |
| 9 | NE. ¼ SW. ¼ 3-27-17 | 5,347 | 1,341 | 1,343 | 120 fluid, 50 per cent oil |
| 10 | SW. ¼ SW. ¼ 3-27-17 | 5,349 | 1,337 | 1,505 | Drilled through Dakota to top of Mc Elmo as test. Showing of oil at 1,480 feet. Much water. Plugged and abandoned, October, 1926 |
| 11 | SE. ¼ SW. ¼ 3-27-17 | 5,336 | 1,320 | 1,467 | Water, showing of oil 1,321 feet. Approximately on top of structure. Plugged and abandoned |

is to be expected where the producing sand is so thin, and is under hydrostatic-pressure control.

### TOCITO STRUCTURE

The Tocito structure, which was considered the most ideal in the Shiprock district, caused many disappointments. The Gypsy Oil Company leased the tract, paying a $46,000-bonus. Satisfactory drilling progress was made, but almost every sand carried fresh water; the first well was abandoned at a depth of 3,022 feet, without encountering even a showing of oil.

In the spring of 1926, geologists of the Continental Oil Company made a detailed survey of the Tocito structure. At the extreme north end they found a separate closure separated by a fault from the major part of the structure at the south. Arrangements were made by the Continental Oil Company for drilling a well in the NW. 1/4, Sec. 8, T. 26 N., R. 18 W., to test this closure, and a well was spudded in on April 18, 1926. The top of the Dakota was found at a depth of 880 feet, and water rose to an elevation of 400 feet in the hole. The bottom of the Dakota was reached at 1,080 feet, and the well was abandoned at a depth of 1,430 feet in the top of the Navajo sandstone, at which depth the well was flowing 2,000 barrels of fresh water per day. The well has since been sold to the Government for the use of the Indians.

### BEAUTIFUL MOUNTAIN STRUCTURE

The Beautiful Mountain structure is approximately 6 miles southwest of the Tocito and takes its name from Beautiful Mountain, which is adjacent to the structure itself.

The Beautiful Mountain structure is of the anticlinal type, with axis trending northwest and southeast. The Tocito sandstone forms a prominent escarpment almost surrounding the structure. The fold is in reality made up of two parts separated by what is believed to be a small saddle. Wind-blown sand and an absence of outcrop hide the true geologic structure on the north end of the southern part of the fold, but it was believed that the closure was sufficient to warrant drilling the test well on the southern part of the structure.

In the high area north of the saddle, the Dakota sandstone is exposed throughout in an area of approximately one-quarter of a section. The whole structure is adjacent to the Chuska Mountains on the west. The Tocito sandstone dips away from the west escarpment of the structure into a sharp syncline and rises on the flanks of the Chuska Mountains. The Dakota formation also is exposed there.

The Navajo Company was formed to develop the lease on the southern closure and drilled a test well, 3,290 feet deep. The location is on the apex of the structure, where considerable Mancos shale has been eroded, so that the Dakota sandstone, carrying fresh, soft water, was reached at a depth of 275 feet. At 1,727 feet a fair showing of 40°-gravity oil was found in the Navajo sandstone (red beds) but not in commercial quantities. The well never obtained production and was sold to the Government as a water well. The flow is unrestricted, and a few small globules of oil rise to the surface of the water. It is thought that this oil comes from the 1,727-foot horizon.

### CHIMNEY ROCK STRUCTURE

About 6 miles northeast of Shiprock is Chimney Rock, the sixth structure to be drilled on the reservation. This structure was not discovered until the early part of 1926. It was mapped in detail by both the Marland and Continental Oil companies and was offered with several other tracts at the second Navajo lease sale held in June, 1926. Like Table Mesa, the geology of the Chimney Rock structure was rather difficult to determine because concretionary beds of brown limestone in the Mancos shale had to be used in mapping the structural details.

Above the lowest closing contour there is about 70 feet of closure with possibly a maximum of 110 feet. The structure is a dome-like anticline about 3 miles long and 2 miles wide, having the southern end truncated and closed by a fault with 50-80 feet displacement. The downthrow is toward the north. This fault is approximately ¾ mile south of the apex of the structure.

The Marland Oil Company purchased the lease and contracted with the Continental Oil Company to drill the test well for them. The well was located in the SW. ¼ of the SE. ¼, Sec. 34, T. 31 N., R. 17 W., and drilling commenced October 6, 1926. The Tocito sandstone was reached at a depth of 605 feet, and from 625 to 640 feet a small flow of gas was encountered which was estimated at 50,000 cubic feet per day. Drilling was continued to the Dakota at a depth of 1,425 feet, where only sulphur water was found. The hole was abandoned at 2,000 feet in January, 1927, without a showing of oil.

### MANCOS CREEK

The Mancos Creek structure is located 20 miles northwest of Shiprock on the Ute Indian Reservation in Montezuma County, Colorado. All the wells are in T. 32 N., R. 18 W. This structure is not well defined

and is reported to consist of a structural terrace of small area. Wells have been drilled to the Dakota at depths ranging from 600 to 700 feet. With the exception of small showings of oil, the Dakota formation in the Mancos Creek structure has produced nothing but water. Some shale oil of 36°-A.P.I. gravity has been obtained above the Dakota, and several wells are being pumped. Altogether 12 wells have been drilled, although but 3 were operated in May, 1928, giving a total combined production of 115 barrels for the month.

### RELATION OF OIL ACCUMULATION TO STRUCTURE

The producing fields and unproductive structures in the Shiprock district have been discussed in some detail because by considering the entire group and their peculiar characteristics it is thought possible to bring out any relations that shed light on the peculiarities of oil accumulation in this section. The writer believes that a detailed study of this district might reveal many additional factors having an important bearing on the accumulation of oil and possibly on its origin. The present survey can do no more than suggest factors which might lead to a solution of the problem.

Of the six structures drilled on the Navajo Reservation, three have proved to be oil fields. The oils produced are similar, yet each is different from the others. Rattlesnake oil is of 74° gravity; Hogback, 63°; and Table Mesa, 58°. The conditions of occurrence also are different. At Rattlesnake, the oil is accompanied by gas which forms the propulsive force producing the oil. At the other two fields the hydrostatic pressure of water in the Dakota sand is the controlling force. Wells at Hogback have continued to flow, however, whereas at Table Mesa they now have to be pumped to keep the water from holding back the production.

### FACTORS AFFECTING ACCUMULATION

Many questions arise in considering the problem of oil accumulation in the Shiprock area. Why should Rattlesnake, Hogback, and Table Mesa be productive when three other structures in the same vicinity are barren of oil? Have Hogback and Table Mesa crudes been "weathered" in place in the sand or during migration and thus freed of the butane and propane gas which at one time they might have contained, or did they undergo a different genesis? Why does Chimney Rock have gas in the Tocito sand and water in the Dakota although no other structure in the district has had free gas unassociated with oil? It is not difficult to understand why Mancos Creek contains water in the Dakota,

because its structure is not a sufficient trap to serve as an accumulating reservoir; but why should sandy shale lenses or pockets above the sand furnish oil having gravity and characteristics entirely different from any other oil found in the entire area?

The Shiprock district is exceptionally well adapted for a study of the problem of oil accumulation, because the variables are reduced to a minimum. The same producing sand, the Dakota, underlies each structure and is exposed at the surface a few miles away. Intrusive material is not confined to a single locality, but is evenly distributed with dikes and igneous plugs throughout the area. All of the folds are situated in the same physiographic or geologic basin.

Table VII presents the important data concerning each field or structure, including the Mancos Creek terrace, which should be considered in studying the problem of accumulation. Some of the factors or features of each structure are briefly discussed.

###### DEPTH TO TOCITO SAND

In so far as the accumulation of oil is concerned, depth to the Tocito sand is of no importance and is mentioned only to give the reader an idea regarding the position of each structure in the stratigraphic column.

###### OBJECTIVE SAND

The objective sand for drilling in each structure is the Dakota, as test wells by this time have demonstrated the barrenness of all other formations so far as oil is concerned. The fact that the Dakota underlies each structure within easy drilling depth and has been found both productive and nonproductive indicates that the accumulation of oil does not depend on the presence of the Dakota, but on some other feature. The characteristics of lenticularity and other features such as porosity and sand thickness are about the same throughout the region. The Dakota is also coal-bearing in the entire district, and comparative data on the carbon ratio of coals in the same horizon could possibly be secured to determine whether any relation exists between the fixed-carbon content and oil accumulation.

###### AVERAGE DEPTH TO DAKOTA

The depth to the Dakota seems to have no bearing on accumulation, particularly with respect to the characteristics of the structures as they now exist, although depth might have had some influence after folding took place and before erosion reduced the depth to the sand. On the Table Mesa and Chimney Rock structures the Dakota is found

deeper. For each field the average depth to the Dakota was obtained by averaging the depths to the sand in all the producing wells.

### THICKNESS OF OIL SAND

The oil-bearing parts of the Dakota seem to differ in thickness in the three producing fields. Rattlesnake has the most oil-productive sand, with a total thickness of approximately 28 feet, although as many as three benches compose the stratum. Hogback has approximately 8 feet of productive sand directly in the top part of the Dakota group. The lower benches of sand which correspond with those producing in Rattlesnake carry nothing but water. In Table Mesa the productive horizon is very thin—approximately 4 feet thick.

The factor controlling the thickness of oil-producing sand is unknown, but it is possible that sand porosity is influential; however, the entire Dakota group seems to drill the same in each field. It is believed that the higher hydrostatic head of water above Hogback and Table Mesa, because of its flushing action, might be responsible for the lack of oil in more than the top member of the Dakota.

### GRAVITY OF OIL

The most striking difference in the three producing fields is the variation of oil gravity. All the oil is exceptionally high in gravity and can be used in any automobile as gasoline without refining. There are varying degrees of high gravity, however. Rattlesnake oil directly from the well has a gravity of approximately 76° A.P.I., but within 24 hours it weathers to a gravity of 63.5° (refer to distillation data on Rattlesnake crude) because of the escape of large quantities of propane and butane gases. The gravity after weathering is the same as that of Hogback crude, and this fact may be important in considering the genesis and accumulation of oil in the Shiprock district. Hogback crude contains no gas whatever, and the question arises as to whether at one time gas was associated with the oil at Hogback, and at a later time was dissipated in some manner. Table Mesa contains no gas, and the oil from this structure is still lower in gravity, 57° to 58°.

### SIZE OF PRODUCING AREA

The size of each oil pool is shown in Table VII. It is of interest to note that Rattlesnake, with the largest producing area, has the oil of highest gravity with associated gas. Hogback, next in size, has the next highest gravity, and Table Mesa, smallest in area, has the heaviest crude of the three structures.

TABLE VII

DATA ON SHIPROCK STRUCTURES

| *Field or Structure* | *Rattlesnake* | *Hogback* | *Table Mesa* | *Chimney Rock* | *Tocito* | *Beautiful Mountain* | *Mancos Creek* |
|---|---|---|---|---|---|---|---|
| Depth to Tocito sand, in feet | On surface | On surface | 455 | 605 | On surface | Escarpment around structure | Surface below Tocito |
| Objective sand.................... | Dakota | Dakota | Dakota | Dakota | Dakota | Dakota | Dakota Sandy shale lenses |
| Average depth to Dakota, in feet | 748 | 725 | 1,331 | 1,425 | 842 | 275 | 650 |
| Total thickness of oil sand, in feet | 28 | 8 ± | 4 ± | | | | ? |
| Results secured | Commercial field | Commercial field | Commercial field | Water well | Water wells | Water well | Small pumping wells |
| Gravity of oil in degrees | 70-74 | 63 | 57-58 | | | | 36 |
| Gas present | Yes | No. Hydrostatic flow | No. Hydrostatic control | 50,000 cu.ft.in Tocito sand | No | No | No |
| Size of producing area, in acres | 800-900 | 260 | 160 ± | | | | Unknown Small |
| Area within lowest closing contour, in acres | 10,000 ± | 20,000 ± | 6,000 ± | 4,000 ± | 17,000 ± | 3,000 ± | ? |
| Total closure, in feet | 350 ± | 500 ± | 150 ± | 70-110 ± | 300 ± | 60 ± | ? |
| Closure above water line, in feet | 20-60 | 15-35 ± | 15 ± | | | | |

TABLE VII—*Continued*

DATA ON SHIPROCK STRUCTURES

| | *Rattlesnake* | *Hogback* | *Table Mesa* | *Chimney Rock* | *Tocito* | *Beautiful Mountain* | *Mancos Creek* |
|---|---|---|---|---|---|---|---|
| Average surface elevation, in feet | 5,306 | 5,076 | 5,340 | 5,230 | 5,750 ± | 5,900 ± | 5,000 ± |
| Subsurface elevation of producing sand at top of structure, in feet | 4,580 | 4,375 | 4,009 | 3,805 | 4,908 ± | 5,625 | 4,350 ± |
| Subsurface elevation of water line, in feet | 4,510 on west; 4,550 on east | 4,340 on west; 4,355 on east | 3,994 ± | | | | |
| Difference in elevation of producing sand and of its outcrop, in feet | 703 ± lower | 908 ± lower | 1,274 ± lower | 1,478 ± lower | 375-1,092 ± lower | 375 ± lower, or 342 higher | 1,650 ± lower |
| Faults | 3 minor | 2 minor | 1 minor | 3; 1 with 65 feet displacement | Yes | ? | ? |
| Reservoir pressure in pounds per square inch | 280 March, 1928 | Average 417 | 553 ± | 640 ± | | | |
| Average closed-in pressure, in pounds per square inch | 44 March, 1928 | 193 when drilled 182 Apr. 3, 1925 172 Jan. 1, 1926 | 110-140 when drilled | | | | |
| Type of water | Sulphur | Sulphur | Sulphur | Sulphur | Fresh | Fresh | ? |

### AREA WITHIN LOWEST CLOSING CONTOUR

The size of the structure evidently has had no influence upon accumulation, because Hogback is twice as large as Rattlesnake, and Tocito, with an area of 17,000 acres, is entirely nonproductive. Table Mesa, with an area of 6,000 acres, is a producing field.

### TOTAL CLOSURE

The Rattlesnake structure, with a total closure of approximately 350 feet, has a much larger accumulation of oil than Hogback, with approximately 500 feet of closure. Tocito has a total closure of approximately 300 feet, but is entirely barren of oil.

### CLOSURE ABOVE WATER LINE

As would be expected in structures of almost the same shape and degree of dip, the amount of closure above the water line is the greatest in the field with the largest producing area.

### SURFACE ELEVATION

Surface elevation is of importance only in determining the subsurface elevations in the different fields. Hogback has a lower surface elevation than any of the other structures, but this condition indicates nothing directly regarding the accumulation of oil.

### HYDRAULIC THEORY OF ACCUMULATION

The hydraulic theory has been so well defined and discussed by Munn,[1] Shaw,[2] Rich,[3] Parks,[4] McCoy,[5] and others, that only a brief explanation will be given, namely, the migration of oil and gas due to the movement of underground water, which carries the oil and gas with it.

Rich[3] states:

> Accumulation results from the selective segregation of the oil and gas which, on account of their buoyancy, always tend to work their way upward toward the roof of the reservoir as they are carried along by the water, and so are caught and retained in anticlinal or similar structural traps, or in places where differences in porosity cause a selective "screening" action, which permits the

[1] M. J. Munn, *Econ. Geol.*, Vol. 4 (1909), pp. 141-57 and 509-29.

[2] E. W. Shaw, *Econ. Geol.*, Vol. 13 (1918), pp. 207-25.

[3] John L. Rich, *Econ. Geol.*, Vol. 16 (1921), pp. 347-71.
*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 7 (1923), pp. 213-26.

[4] E. M. Parks, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 6 (1924), pp. 697-715.

[5] Alex W. McCoy, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 11 (1926), pp. 1015-34.

passage of the water but holds back the oil and gas. * * * Where the water movement is especially rapid, there is not only a tendency for accumulation to be restricted to the sharpest and most effective traps, but the action may be carried still farther and cause the dissipation and removal of accumulations which have already gathered in the traps before they became affected by an increase in rate of water circulation. This removal of oil and gas accumulations by the action of moving water has been called "flushing." * * *

The writer believes that the circulation of waters in the Dakota sandstone in a general movement from east to west has been responsible for the migration of the oil accumulated in the higher domes of the Shiprock region, and that the same forces have caused the flushing of the lower domes so as to prevent the accumulation of oil. Although two of the barren domes are as high above the basin floor as those that produce, or even higher, they are controlled by a different set of conditions and are immediately adjacent to the only fresh- or meteoric-water intake on the west rim of the basin.

The only factors in Table VII which seem to show a definite relation to accumulation are those relating to the subsurface elevation of structures as compared with the elevation of the Dakota sand at its outcrop. The subsurface elevation of each structure, at least in this district, is important, as are the elevations of the various oil-water contacts and the reservoir pressures. These factors will be discussed in connection with the influence that circulating water is thought to have had on accumulation.

An important fact to know is that the San Juan basin, of which the Shiprock district comprises the western part, is a large, nearly circular artesian basin with the intake rim of the Dakota sandstone at elevations ordinarily ranging from 6,000 to 9,000 feet above sea-level in mountainous regions on the north, northeast, and east sides of the basin. Large quantities of meteoric water from rainfall and snowfall, and from springs, gain access to the Dakota on these sides. On the northwest side of the basin, west of Shiprock, the Dakota is much lower, with an elevation of about 5,100 feet.

From a knowledge of closed-in pressures of wells in the producing fields, the depths of the wells, the elevation of the oil-water contact, and the gravity of the oil, it has been a simple matter to calculate the approximate reservoir pressures as given in Table VII. By converting all of these pressures into hydraulic head in feet, figures are obtained representing the approximate head of water or height in feet that the effective water column extends above each structure. For Rattlesnake, the pressure is equivalent to a column of water reaching to an elevation of

5,226 feet; for Hogback, to 5,338 feet; and for Table Mesa, to 5,286 feet. These figures correspond closely; the average is 5,283 feet, indicating that the effective water column of the Dakota rises to an average elevation of 5,283 feet above sea-level around the basin. As compared with the elevations given for the outcrop of the Dakota, there is a discrepancy, but it is believed that if the entire rim of the basin on the east is considered, the figure is correct, because there would be some loss of head through seepage and springs.

The hydraulic theory maintains that the intake area of an artesian basin can not be favorable for the accumulation and retention of oil because of the strong flushing action to which the sands doubtless are subjected. Structures in the vicinity of the low outlet rim, however, should be favorable territory, as the oil which has been gathering into the sandstones throughout the extent of the basin is being carried toward them by the artesian water.

The Dakota sandstone crops out in Red Wash approximately 10 miles west of Rattlesnake and extends south and east approximately 36 miles until hidden by overburden or wash from the Chuska Mountains and younger formations (Fig. 1). The elevation of this Dakota outcrop is approximately 5,100 feet due west of Rattlesnake and about 6,000 feet west of the Beautiful Mountain structure.

Very little meteoric water gains admittance to the Dakota through its western outcrop, however, except in the vicinity of Beautiful Mountain, as the region is very arid, with a mean annual rainfall of approximately 5.92 inches. Opposite the Tocito and Beautiful Mountain structures a few springs and short streams of permanent or intermittent flow emerge from the mountains. Most of this water is fresh and is derived from snow and rainfall. Because of the arid condition of the soil, probably 90 per cent of the rainfall along the western rim of the basin, exclusive of the Beautiful Mountain district, is dissipated by rapid run-off into dry creeks, and most of the remaining 10 per cent is lost by evaporation.

As the Dakota sandstone has an average thickness of 175 feet and as it is exposed throughout a distance of many miles, it is known that evaporation takes place from a considerable sand surface area. The climatic conditions of the Navajo country favor high evaporation, particularly during the summer months. According to Gregory,[1] at Hol-

[1]H. E. Gregory, "The Navajo Country—A Geographic and Hydrographic Reconnaissance of Parts of Arizona, New Mexico, and Utah," *U. S. Geol. Survey Water Supply Paper 380* (1916).

brook, Arizona, where the average rainfall is 9.15 inches per year (more than in the Shiprock district), the measured amount of evaporation in a period of four years was a mean of 46.41 inches; that is, the evaporation was 300 - 400 per cent greater than the rainfall at that station. For the Shiprock district the evaporation would be as much or more, except in the mountain uplands.

Evaporation and a continual small wastage of water in occasional springs at the base of the Dakota outcrop throughout a long time undoubtedly would serve as an outlet and cause a continual circulation of water from the higher rims of the basin to the lower edge at the west.

Another indication that the underground movement of water is from east to west is shown by the tilted position of the oil-water contact line in the Hogback and Rattlesnake fields (Table VII). In Rattlesnake the water line on the west is 40 feet lower and in Hogback 15 feet lower than the oil-water contact on the eastern side of the structures.

An additional tendency toward movement of water would be the loss of water through springs at the base of, or in the vicinity of, numerous dikes in the region. As mentioned previously, there is reason to believe that the dikes are of post-Mancos time and that they cut through the Dakota and its overburden of Mancos shale so as to open channels which allow the escape of Dakota water. Along the dikes between Table Mesa and Rattlesnake the spring water is bitter and has a sulphurous odor very similar to the water encountered in wells drilled to the Dakota on the several structures. A spring at Tocito store yields fresh, palatable water. Its source undoubtedly is in the Beautiful Mountain area of fresh-water supply.

With water circulation established, the smallest accumulation of oil, or perhaps barrenness, would be expected in the structure situated at the greatest depth below the sand outcrop, because of the flushing action of the greater hydrostatic head of water. In the Shiprock district, the Chimney Rock structure was found to be nonproductive, as its subsurface Dakota elevation of 3,805 feet was the lowest of the seven structures. Table Mesa, a very small field, with a subsurface elevation of 4,009 feet, has produced a considerable amount of water with the oil from the beginning of its life. Compared with Hogback and Rattlesnake, the gravity of the Table Mesa oil is the heaviest; it is possible that many of its gaseous and lighter constituents were dissolved in water and carried to other localities. The Hogback structure, with a subsurface elevation of 4,375 feet, is next in height and has probably received less flushing

than the other two. It has a larger producing area and oil of higher gravity than Table Mesa. Rattlesnake has an elevation on top of the Dakota of 4,580 feet, and is the highest of the producing fields. This structure undoubtedly received a minimum of flushing; it therefore carries the largest accumulation of oil with the highest gravity and plenty of gas very rich in propane and butane.

According to the foregoing discussion, the Tocito and Beautiful Mountain structures, with higher subsurface elevations of approximately 4,908 and 5,625 feet, respectively, should have had accumulations of oil and gas. If they had been situated in the territory of Rattlesnake or Hogback, away from the only source of fresh water in the region, it is believed that they would be productive. The two structures seem to be controlled by a different set of hydrostatic conditions. On the west they are immediately adjacent to a mountainous region which is capable of furnishing a perennial supply of fresh water to them through the Dakota sand, where its elevation is much higher than on the apex of the structures. This supply of water is under a sufficient head to offset any possible movement of underground water from the east and possibly established a general circulation toward the north.

There is a possibility also that the dike system between Table Mesa and the Tocito and Beautiful Mountain structures, assuming that it cuts through the Dakota, has isolated them from any hydrostatic control from the east. Even if the dike had no influence, their elevations and positions are such as to place them in the same category with structures on the inlet rim, which are generally nonproductive. Both Beautiful Mountain and Tocito structures carry large quantities of fresh artesian water in the Dakota.

The writer believes that a study of water analyses from the Dakota in the Shiprock region would show even more conclusively the important part that circulation of waters has had in oil accumulation. Several analyses of Hogback water are available but are not conclusive; most of them represent mixed waters. The analyses do show, however, that the Dakota water, as compared with what is believed to be connate water in a sandy horizon at a depth of approximately 550 feet in well No. 9, has been considerably diluted and altered. The water analysis for Compton No. 2 well is of a true Dakota sample (Fig. 3).

In the Salt Creek field, Wyoming, the most productive parts of the structure were those which analyses showed to have the least dilution or flushing by meteoric water; the comparatively barren district of the southern part of the field carries water which has been very greatly diluted.

The escape of possible oil accumulations from Tocito and Beautiful Mountain through faults is unlikely because the faults are small, and there would be some surface indication of oil seepage or springs.

The presence of gas in the Tocito sand at Chimney Rock has been mentioned; it is the writer's belief that Hogback and Table Mesa also might, at one time, have contained gas which was later dissipated. It is possible that some of the gas from the Hogback structure has migrated to the Tocito sand at Chimney Rock and at Rattlesnake—carried to these structures dissolved in water. Chimney Rock has a large fault traversing it which might have permitted the movement of gas from the Dakota up into the Tocito and its accumulation in that formation; or migration could possibly have taken place through the Tocito before erosion dissected the formation from Hogback.

Hogback is crossed by two or three normal faults of moderate displacement of approximately 16 feet, but data on subsurface conditions are not complete enough to determine whether or not these faults disappear with depth. Their presence, however, as deep as the first water-bearing sand in the Dakota, is indicated by the finding of much fault breccia with a considerable amount of calcareous cementing material. This is very similar to calcareous tufa. It was observed along a fault plane near the northwest corner of Section 19. Probably an upward circulation of waters through the fault from the Dakota sandstone deposited this material.

In the drilling of wells No. 7 and No. 8, the driller reported the presence of oil in small amounts and the stain of oil in the shale above the Dakota. These wells are close to the fault and are located on the downthrown side at the surface.

Bruce M. Barnard,[1] of Shiprock, informed the writer that prior to a big flood in 1911, Indians reported the presence of oil seepages in the Chaco River bottom at Hogback. He stated also that they collected this oil in sufficient quantities for burning.

Approximately 33 miles east of Hogback in the Bloomfield district small deposits of high-gravity oil similar to Hogback crude are found, but these accumulations are not in well-defined structures. According to Reeside[2] and others, the occurrence of oil and gas at Bloomfield Mesa is controlled by the presence of shale-sealed sandstone lenses.

[1]Personal communication.

[2]J. B. Reeside, Jr., W. W. Boyer, and G. H. Hanson, "The Bloomfield Mesa Oil and Gas Field, San Juan County, New Mexico," *U. S. Geol. Survey Press Notice 4548* (January 8, 1926).

Where oil has been found in quantities sufficient for production, the drill ordinarily has released gas first, then oil, and finally salt water. Drilling operations have shown that where the sand contains oil, it also carries salt water. Where wells have passed through the producing zone and have not found oil, salt water is also absent.

To a certain extent this condition is found in the Shiprock district, although it is not everywhere encountered in the Dakota. For stray sand lenses above the regular producing sand, however, the statement is true; although water may not be detected immediately, it is generally present.

To the writer the evidence indicates very strongly that the hydraulic theory accounts for the peculiarities of oil accumulation on the Navajo Reservation, and that circulating waters and the effect of hydrostatic pressure have been controlling factors.

# HISTORY OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS[1]

SIDNEY POWERS[2]
Tulsa, Oklahoma

ABSTRACT

The American Association of Petroleum Geologists was organized in Tulsa, Oklahoma, in 1917, by the petroleum geologists of the Southwest. From a beginning of 94 members it has grown to be the largest geological society in the world, with a membership of more than 2,000 at the end of 1928. Its members live in 41 states and 29 foreign countries. The Association's official monthly *Bulletin*, containing papers contributed by the members, reflects the progress of the science of petroleum geology.

## INCEPTION, 1915

The American Association of Petroleum Geologists was organized as the Southwestern Association of Petroleum Geologists in Tulsa, Oklahoma, February 10, 1917. The name was changed at the meeting in Oklahoma City, February 16, 1918, upon the recommendation of J. Elmer Thomas, the president at that time.

The use of petroleum geology in Oklahoma commenced in 1913, at which time several of the larger companies employed geologists. The increase in the number of geologists in commercial employment was slow during 1913-15, and the need for exchange of geologic thought in the Mid-Continent region was not felt until 1915. Early in that year, E. L. DeGolyer, who was chief geologist for the Mexican Eagle Oil Company at Tampico, and temporarily a resident of Norman, proposed the organization of a geological society, as a University extension project, to Charles H. Taylor, then head of the department of geology at the University of Oklahoma, and Professor Taylor assumed the initiative in interesting other geologists.

Most of the petroleum geologists in Oklahoma, less than 50 in number, had headquarters in Tulsa. Among others, J. Elmer Thomas, then geologist for the Minnehoma Oil Company, started a movement to organize the petroleum geologists quite independently of Taylor's

[1]Manuscript received by the editor, November 1, 1928.

[2]Consulting geologist, Amerada Petroleum Corporation.

effort to organize all geologists as a University project. During the summer of 1915 the matter was discussed by many of the Tulsa geologists. At one of the informal gatherings Harry R. Johnson, C. L. Severy, H. B. Goodrich, and J. Elmer Thomas decided that some kind of a meeting should be held. The question of establishing a branch of the American Institute of Mining Engineers in Tulsa was raised at several informal gatherings and dinners from 1914 onward and at the first Tulsa meeting in 1917.

On September 8, 1915, Mr. Thomas, on his own initiative, sent out invitations to an informal dinner of geologists and on September 25, announced the date of the dinner as October 2. Reservations were made at the Hotel Tulsa for 32, and 27 geologists were present.

A partial list of those who attended the first dinner of petroleum geologists in the state follows:

| | | |
|---|---|---|
| Robert W. Brown | R. E. Garrett | C. W. Shannon |
| Alan Bruyere | Burton Hartley | Carl D. Smith |
| Everett Carpenter | L. L. Hutchison | Charles H. Taylor |
| R. A. Conkling | Alex W. McCoy | J. Elmer Thomas |
| Clifton S. Corbett | H. H. McKee | M. M. Valerius |
| C. R. Eckes | G. C. Potter | Lucien H. Walker |
| F. Julius Fohs | F. R. Rees | Harry E. Wright |
| J. H. Gardner | R. J. Riggs | |

### FIRST MEETING, NORMAN, 1916

Charles H. Taylor, Chairman

It was decided at the dinner that an association should be organized according to the proposal of Charles H. Taylor and invitations were mailed on October 25 by him for a geological conference to be held in Norman the next month. The meeting was postponed until January 7-8, 1916. Mr. Taylor, as chairman, and C. N. Gould presided at this meeting. Mr. Taylor also presided at a dinner served in the Physics Laboratory. This was a meeting of the geologists of the Southwest and not primarily of petroleum geologists.

A partial list of the 50 or more geologists present is given. An asterisk (*) indicates A. A. P. G. members in 1928:

| | | |
|---|---|---|
| W. R. Berger* | John M. Herald* | Irving Perrine* |
| Ed. Bloesch* | C. E. Hyde* | W. E. Pratt* |
| R. W. Brown* | L. L. Hutchison* | F. R. Rees* |
| W. E. Brown | Grady Kirby* | E. W. Scudder* |
| R. A. Conkling* | W. C. Kite* | C. W. Shannon* |

| | | |
|---|---|---|
| E. L. DeGolyer* | W. A. Knott | W. M. Small* |
| A. C. Dennis | Harve Loomis* | L. B. Snider* |
| Alexander Deussen* | A. A. McCullough | L. C. Snider* |
| W. E. Dodge | A. W. McCoy* | C. H. Taylor* |
| C. R. Eckes* | H. H. McKee* | L. E. Trout* |
| A E. Fath* | M. G. Mehl* | W. A. J. M. van der Gracht* |
| G. P. Ferrell | P. R. Morrow | J. A. Udden* |
| J. H. Gardner* | F. P. Mulky* | A. J. Williams* |
| R. E. Garrett* | M. J. Munn* | W. E. Wrather* |
| C. N. Gould* | G. H. Myers | H. F. Wright* |
| C. A. Hammill* | J. B. Newby* | Earl Youngmeyer |

The following papers, among others, were read. A figure (1) indicates publication in Volume 1 of the *Bulletin*.

1. Ed. Bloesch, North-South Correlation of the Pennsylvanian of Oklahoma (1)
2. E. L. DeGolyer, Geology of the Oil Fields of Mexico
3. E. L. DeGolyer, Significance of Seepages as an Indication of Oil Fields
4. C. R. Eckes, Geologic Correlation in the Osage
5. C. N. Gould, Geological Work in the Southwest (1)
6. W. C. Kite, An Outline of a Type Report on an Oil Field (1)
7. A. W. McCoy, Some Effects of Capillarity on Oil Accumulation (1)
8. W. E. Pratt, Haworth's New Instrument for Geologic Mapping
9. C. H. Taylor, The Granites of Kansas (1)
10. J. Elmer Thomas, (read by H. H. McKee) "Doodlebugs" and the Licensing of Geologists
11. W. A. J. M. van Waterschoot van der Gracht, The Saline Domes of Northwestern Europe (1)
12. W. E. Wrather, Notes on the Texas Permian (1)
13. Johan A. Udden, Hints to Prospective Geologists (1)

Questions which engrossed attention were the origin of salt domes (then thought to have arisen by the Harris theory of the linear force of growing crystals); the origin of the granite found by wells drilled on certain anticlines in Kansas (reported by some geologists as "impossible" and by others as intrusive); the advisability of licensing geologists, because of the number of "quacks" engaged in "locating" oil; and the oil fields of Mexico with reference to both the enormous yield of the wells and to the opportunities for university graduates to obtain employment.

Before the close of the meeting it was decided not to perfect an organization, but to hold the next meeting at Tulsa. A committee composed of C. H. Taylor, chairman, C. W. Shannon, F. R. Rees, and W. E. Wrather was delegated to take charge of arrangements for that meeting.

SECOND ANNUAL MEETING, TULSA, 1917

Officers elected:

J. Elmer Thomas, president
Alexander Deussen, vice-president
M. G. Mehl, secretary-treasurer
C. H. Taylor, editor-in-chief

The first Tulsa meeting, February 9-10, 1917, led to the permanent organization of the petroleum geologists of the Southwest. About 50 geologists attended this meeting, but the registration list is not available. The program of the meeting read: "Program of the Second Annual Meeting of the Geologists of the Southwest." Arrangements were in charge of E. J. Cragoe, then professor of geology, Henry Kendall College. This, again, was not designed as a gathering of petroleum geologists, but owing to their preponderance at the meeting the name adopted was "Southwestern Association of Petroleum Geologists." Efforts to have this group affiliated with the American Institute of Mining Engineers were unsuccessful.

The first published list of members of the Southwestern Association, May 19, 1917, which is reprinted from Volume 1 without additions, gives 94 members, and includes the names of most of those present. An asterisk (*) indicates A.A.P.G. members in 1928; (†), deceased.

ACTIVE MEMBERS

E. G. Allen*
F. L. Aurin*
R. F. Baker*
J. G. Bartram*
C. M. Bauer*
Ed. Bloesch*
H. E. Boyd*
R. W. Brown*
G. H. Burress*
G. E. Burton*
W. R. Calvert*
R. A. Conkling*
E. J. Cragoe
C. L. Cumming
W. W. Cutler*
L. R. Dawson
C. E. Decker*
E. L. DeGolyer*
Alexander Deussen*
L. G. Donnelly*
N. F. Drake*
H. D. Easton*
C. R. Eckes*
A. E. Fath*
O. Fischer*
F. J. Fohs*
W. H. Foster*
J. H. Gardner*
D. L. Garrett
C. N. Gould*
F. C. Greene*
W. F. Grube†
C. A. Hammill*
H. H. Harper*
Burton Hartley*
Erasmus Haworth*
Huntsman Haworth*
W. P. Haynes*
R. S. Hazeltine*
K. C. Heald*
J. M. Herald*
E. P. Hindes*
C. W. Honess*
J. S. Hook
J. V. Howell*
L. L. Hutchison*
J. S. Irwin*
T. F. Jackson
Wm. Kennedy†
C. T. Kirk*
W. C. Kite*
Marvin Lee*
Harve Loomis*
A. W. McCoy*
A. A. McCullough
M. G. Mehl*
W. J. Millard*
V. E. Monnett*
R. C. Moore*
G. H. Myers
J. B. Newby*
E. C. Parker*
J. R. Pemberton*

| | | |
|---|---|---|
| Irving Perrine* | E. W. Scudder* | W. A. J. M. van der Gracht* |
| C. L. Porter | C. L. Severy* | V. V. Waite* |
| Sidney Powers* | W. M. Small* | A. J. Williams* |
| S. S. Price* | C. K. Springfield | S. M. Willis |
| F. S. Prout* | D. M. Stacey* | E. G. Woodruff* |
| I. A. Pynch | C. H. Taylor* | W. E. Wrather* |
| R. J. Riggs* | J. Elmer Thomas* | H. F. Wright* |
| J. M. Sands* | Johan A. Udden* | |

ASSOCIATE MEMBERS

| | | |
|---|---|---|
| W. R. Berger* | J. H. Hinds | G. W. Witteveen* |
| E. H. Davis | Hugh MacKay* | |
| I. H. Grove | F. P. Mulky* | |

The Tulsa sessions were held in the Hotel Tulsa, Henry Kendall College (now University of Tulsa), Methodist Episcopal Church, and Y. M. C. A., and were presided over by Charles H. Taylor, C. W. Shannon, W. E. Wrather, and J. Elmer Thomas. On motion of C. W. Shannon a business committee consisting of the following geologists was appointed: F. L. Aurin, chairman, V. E. Monnett, J. H. Gardner, R. C. Moore, and W. E. Wrather. This committee recommended that the organization be perfected and known as "The Southwestern Association of Petroleum Geologists," that the officers consist of a president, vice-president, and a secretary-treasurer, and suggested the following names for these offices in the order given: J. Elmer Thomas, Alexander Deussen, and M. G. Mehl. These suggestions, in the form of motions, were carried. The office of editor-in-chief was created and C. H. Taylor elected by ballot. A committee to draft a constitution and by-laws was appointed by the president: W. E. Wrather, chairman, M. M. Valerius, J. B. Newby, E. G. Woodruff, R. S. Hazeltine, and C. L. Severy. The constitution was drawn up later and was officially adopted at the Oklahoma City meeting. An abstract from the constitution and by-laws pertaining to membership and dues was mailed to all members by the secretary on March 25, 1917.

The program called for discussion of geological reports under the headings: general reconnaissance reports; contour map of undeveloped field; report on specific tract in a developed field; general report on a developed field; miscellaneous reports. Questions were noted on the program as follows:

1. Why is gas two and three cents at the well and from twenty to twenty-five cents to the consumer?
2. Would the process of grouting be practical for stopping caving in drill-holes?

3. (a) Would underground storage for oil be lightning proof? (b) If so, would the expense incurred in preparing underground storage be practical in comparison with the loss of oil by fire in tank storage?

4. Why are so many strings of tools lost in drill holes?

5. Why are the anticlines in east-central Oklahoma not productive of oil?

6. What lines of work is the Federal Survey carrying on in the Southwest at the present time?

Topics for discussion were listed:

1. Future of geology in the Southwest
2. Laws legislated for logs
3. Problems of the State Surveys
4. A comparison of surface and underground dips and their significance
5. A comparison of the amount of cementation of oil-bearing sandstone with the same sandstone when not oil-bearing .
6. Mistakes of field geologists

The president mailed a circular letter to all members on March 23, 1917, urging the transmission of manuscripts for publication, the remittance of dues, and the acquisition of new members. He calls attention to the bright future prospects and writes:

> I believe that assistance that you can render at this time will mean a great deal to the organization. As I see it, the life of the Association is dependent on a strong and enthusiastic membership as a whole, rather than on the officers. I can see no reason why we cannot expect to have between 200 and 300 enthusiastic workers for our membership, scattered over the six or seven states which we represent.

A list of papers presented at this Tulsa meeting follows. Publication in Volume 1 of the *Bulletin* is indicated by the figure (1).

1. M. G. Mehl, The Bearing of the Kansas Granites on Certain Theories to Account for the Shaping of the Primitive Earth
2. J. H. Gardner, The Origin and Nature of Folding (published under the title: The Vertical Component in Local Folding) (1)
3. Dorsey Hager, The Application of Geology to Intensive Development
4. Ed. Bloesch, Observations on Post-Permian Deposits in North-Central Oklahoma (1)
5. C. W. Honess, The Contact Line between the Cretaceous and the Older Rocks to the North in Southern Oklahoma
6. Sidney Powers, Age of the Oil in Southern Oklahoma Fields
7. William Kennedy, Coastal Salt Domes (1)
8. Alexander Deussen, Oil Prospects of Inner Belt of Coastal Domes (1) (published under the title: The Humble, Texas, Oil Field)
9. F. L. Aurin and C. W. Shannon, Geological Review: Oklahoma Geology (published by F. L. Aurin under the title: Correlation of the Oil Sands of Oklahoma)

10. L. L. Hutchison, Pioneering in Geology
11. C. T. Kirk, Significant Features of Western Coal Deposits (1)
12. N. F. Drake, Oil Possibilities in Arkansas
13. K. D. White, Oil Development in Colombia, South America (1)
14. A. F. Crider, Oil and Gas Possibilities in Mississippi (1)
15. C. H. Taylor, The Granites of Kansas (1) (paper of 1916 brought up to date; only one paper published in the *Bulletin*)
    Discussed by Everett Carpenter and M. G. Mehl
16. C. N. Gould, Comparison of the Stratigraphy and Structure of the Seven Mountain Uplifts of the Great Plains (read by title in the absence of the author)
17. G. E. Burton, Filing System for Geological Departments
18. C. W. Shannon, The Relation of Surface Vegetation to Surface Geology
19. Frank Gahrtz, New Maps of Oklahoma (presented by V. V. Waite)
20. R. C. Moore, Geological Review: Kansas Geology
21. H. A. Buehler and E. B. Branson, Geological Review: Missouri Geology
22. Johan A. Udden, Geological Review: Texas Geology

A. G. Heggem gave an address on the second night at the Y. M. C. A. on the subject: "Standardization of Drilling Equipment."

Contemporaneous geologic thought is reflected in the papers presented at meetings and in the ensuing discussions. During 1916 so many wells north of the El Dorado field in Kansas, located by geologists, had penetrated to granite that no doubt remained of the presence of true granite. It had also become evident that the granite wells lay along a north-south ridge which became known as the "Granite Ridge." Surface-structure contour mapping in Oklahoma and Kansas had progressed to the extent that geologists were considering the origin of the low folds which were found to have trapped oil in contrast to the steep folds of southeastern Oklahoma where the geologically located wells were dry holes. Attention was called for the first time to the existence of buried hills, to commercial production of oil in Oklahoma from the Simpson formation of Ordovician age, and to the identification of formations by fossils in well cuttings. Correlation charts of oil sands were being made —the first step in subsurface geological studies, then just beginning. The first paper on geological work in South America was presented.

THIRD ANNUAL MEETING, OKLAHOMA CITY, 1918

Officers elected:

Alexander Deussen, president
I. C. White, vice-president
W. E. Wrather, secretary-treasurer
C. H. Taylor, editor

The third annual meeting was held in the Lee Huckins Hotel, Oklahoma City, February 15-16, 1918, presided over by J. Elmer Thomas, president. It was attended by about 125 members and 75 guests. On the first evening a popular program, arranged by the president to create national interest in the Association, was given at the First Methodist Church, at which addresses were made by T. A. O'Donnell on "The Work of the United States Fuel Administration," by I. C. White on "Gusher Wells of Mexico," by J. F. Kemp on "Geology Applied to Engineering," and by J. H. Gardner on "Mammoth Cave, Kentucky." The second noon the Association was the guest of the Oklahoma Oil and Mining Association at a luncheon and short talks were made by J. F. Kemp, I. C. White, and J. Elmer Thomas. The constitution and by-laws published in Volume 1 were adopted with amendments, the most important being the change of name to the American Association of Petroleum Geologists.

The list of members published in Volume 2, 1918, includes 160 active and 17 associate members, a total of 177, an increase of 83 in one year. Owing to the World War the attendance at the meeting and the rate of increase in membership during most of the ensuing year were lessened.

A list of papers presented follows, notation being made of those printed in Volume 2 (2).

1. C. N. Gould, The Beginning of Things Geological in Oklahoma
2. R. H. Johnson, The Distribution of Underground Salt Water and its Relation to the Accumulation of Oil and Gas (2)
3. Alexander Deussen, Review of the Developments in the Gulf Coast in 1917 (2)
4. Irving Perrine, Geologic Conditions in Central Kansas (2)
5. Sidney Powers, Ordovician Oil in Oklahoma
6. Ed. Bloesch, Value of Petroleum Geology in the Mid-Continent Fields (2)
7. G. E. Burton, New Development for Oil and Gas in Oklahoma during the Past Year and its Geological Significance (2)
8. J. R. Pemberton, Review of the Past Year's Developments in Kentucky from a Geologic Standpoint (2)
9. F. C. Greene, A Contribution to the Geology of Eastern Osage County (2)
10. R. C. Moore, Review of the Past Year's Development of Geologic Interest in Kansas (2) (read by title in absence of author; published under the title: Geologic History of the Crystalline Rocks of Kansas)
11. E. L. DeGolyer, The Geology of Cuban Petroleum Deposits (2) (read by R. S. Haseltine in the absence of the author)
12. A. W. McCoy, The Relation of Former Shore Lines to Oil Accumuation (2) (published under the title: On the Migration of Petroleum through Sedimentary Rocks)

13. W. E. Wrather, Review of the Past Year's Developments of Geologic Interest in Northwest Texas
14. D. W. Ohern, A Contribution to the Stratigraphy of the "Red Beds" (2)
15. Mowry Bates, Review of Oil and Gas Development in Northern Louisiana (2)
16. M. G. Mehl, Some Notes on Woodson County, Kansas (read by title in the author's absence)
17. C. T. Kirk, Review of the Past Year's Developments of Geologic Interest in New Mexico
18. A. E. Robitaille, Review of the Past Year's Developments of Geologic Interest in Wyoming
19. Dorsey Hager, The Geologist and the War (read by title)

The outstanding event of the Oklahoma City meeting was the presence of I. C. White, the originator of the anticlinal theory of the accumulation of oil. He showed moving pictures of the famous Cerro Azul well in Mexico. The presence of Professors Kemp and Salisbury was an inspiration to the members. Mr. O'Donnell advised geologists and oil men not to fear government control on account of the World War, but to find more oil.

Texas, up to this time, had not attracted Mid-Continent oil operators or geologists. The paper by Wrather called attention to north-central Texas, which came into great prominence during the year.

Oil migration interested those who attended the meeting more than any other problem. The experiments by McCoy were becoming widely known and the importance of shore lines as furnishing reservoir rocks was not appreciated until this time.

### FOURTH ANNUAL MEETING, DALLAS, 1919

Officers elected:

I. C. White, president
Irving Perrine, vice-president
C. E. Decker, secretary-treasurer
C. H. Taylor, editor-in-chief

The fourth annual meeting, March 13-15, 1919, in Dallas, was the first meeting after the World War and created such interest that three days were required for the session. The membership list published in Volume 3 included 311 active members, 26 associate members, and 12 active and associate members elect, total 349, a growth of 172 in one year and of 255 members in two years. Two of the active members, R. D. Salisbury and David White, were elected to honorary membership.

Technical sessions were held in the Adolphus Hotel. A popular session was held in the auditorium of the Municipal Building the first

evening, at which addresses were made by David White, Charles Schuchert on "The Relation of Stratigraphy and Paleogeography to the Petroleum Geology," Johan A. Udden on "Oil-Bearing Formations in Texas" (3), and M. L. Fuller on "Exploration in China" (3). The annual banquet was complimentary, by the Dallas Chamber of Commerce and Manufacturers' Association. The chief speaker was Ralph Arnold, whose subject was "Valuation of Oil Properties." Brief talks were made by David White, E. W. Shaw, and C. W. Washburne.

Reports by the secretary-treasurer and editor were not published. No financial report was available at the time of this or the preceding meeting. The editor reported that 1,000 copies of Volume 2 had been printed. The dues were increased from five dollars a year for active and three dollars for associate membership to ten and six dollars, respectively. Patron or life membership was created for active members by the payment of $200.00. Honorary membership was created (but not published). The calendar year was authorized as the fiscal year.

The program specialized on the Ranger "boom" which attracted great attention at the time. Papers listed on the program follow, the first 14 composing a symposium on north-central Texas.

1. Jon A. Udden, Subsurface Geology of the Oil Districts of North-Central Texas (3)
2. C. R. Eckes, D. K. Greger, F. B. Plummer, and V. V. Waite, Description of Cuttings from Individual Wells in North-Central Texas (3)
3. A. W. McCoy, Lithologic Characteristics of the Bend Series
4. E. A. Trager, Laboratory Methods for the Examination of Well Cuttings
5. V. V. Waite, Methods of Examination of Well Cuttings Used by the Bureau of Economic Geology and Technology, Austin, Texas
6. G. H. Girty, The Bend Formation and its Correlation (3). (Also published a paper with R. C. Moore: Age of the Bend Series)
7. J. M. Sands, Structural Conditions in the Bend Series Adjacent to the Llano Uplift
8. W. E. Pratt, Geologic Structures and Producing Areas in North Texas Petroleum Fields (3)
9. R. C. Moore, The Bend Series of Central Texas (3)
10. F. B. Plummer, Preliminary Paper on the Stratigraphy of the Pennsylvanian Formations of North-Central Texas (3)
11. J. W. Beede, Notes on the Structures and Oil Showings in the Redbeds of Coke County, Texas (3)
12. Johan A. Udden, Observations on Two Deep Borings near the Balcones Fault (3)
13. M. L. Fuller *et al.*, Water Problems of the Bend Series (3)
14. R. T. Hill, The Cretaceous Problem as it Relates to the Possibility of Determining Structures in the Underlying Pennsylvanian and Mississippian Formations.

15. Ralph Arnold, Problems of Oil Lease Valuation (3)
16. C. H. Beal, Essential Factors in the Valuation of Oil Properties (3)
17. R. H. Johnson, Decline Curve Methods (3)
18. E. W. Shaw, The Principal Factors of Natural Gas Land Valuation (3)
19. A. W. McCoy, Principles of Oil Accumulation
20. H. R. Shidel, Development of the Butler County, Kansas, Field
21. W. R. Berger, The Extent and Interpretation of the Hogshooter Gas Field (3)
22. W. R. Berger, Review of Developments in Kansas during 1918
23. W. G. Matteson, A Review of the Development in the New North-Central Texas Oil Fields during 1918 (3)
24. S. L. Mason, A Statistical Investigation of the Effects of Structure upon Oil and Gas Production in the Osage (3)
25. Ed. Bloesch, Unconformities in Oklahoma and their Importance in Petroleum Geology (3)
26. E. H. Sellards, Structural Conditions in the Oil Fields of Bexar County (3)
27. J. W. Bostick, The Saratoga, Texas, Oil Field
28. C. R. Eckes, Relation of Sulphur and Cap Rock in the Gulf Coast Salt Domes
29. R. T. Hill, History of Geologic Exploration in the Southwest
30. Donald F. MacDonald, Notes on the Stratigraphy of Panama and Costa Rica (3)
31. Sidney Powers, Geologic Work of the American Expeditionary Force
32. T. W. Gregory, Gas Conservation and Distribution under the U. S. Fuel Administration
33. G. E. Burton, Design for a Log Meter
34. G. S. Rogers, Some Oil Field Waters of the Gulf Coast (3)
35. C. W. Washburne, Some Physical Principles of the Origin of Petroleum (3)

Taxation of incomes from oil production by means of complicated laws and regulations led geologists into appraisals and estimations of oil reserves during and after the war. Drawing decline curves replaced mapping surface outcrops as an occupation for many geologists.

North-central Texas attracted the attention of all. Lengthy discussion of correlation problems by lithologic and microfaunal evidence led to correct age determinations of uppermost Mississippian and lowermost Pennsylvanian formations in succeeding years. The excellent microscopic work instituted at the Bureau of Economic Geology at Austin, Texas, by Johan A. Udden stimulated the use of micropaleontology in subsurface work.

FIFTH ANNUAL MEETING, DALLAS, 1920

Officers elected:

Wallace E. Pratt, president
Alex W. McCoy, vice-president
Charles E. Decker, secretary-treasurer
Raymond C. Moore, editor

The fifth annual meeting was held at the Adolphus Hotel, Dallas, as was the preceding meeting. The sessions lasted from March 18 to 20, inclusive. Complete accounts of this and subsequent meetings are published in the annual volumes; therefore, only a brief mention of noteworthy events is given here.

At the business meeting, regional sections were authorized and a standard of professional ethics was adopted. An annual salary for the secretary-treasurer was authorized. The first official treasurer's report was made, showing receipts of \$3,995.19 and a balance on hand of \$926.89. The *Bulletin* was printed by the University of Kansas Journalism Press from 1920 to 1923 instead of in Oklahoma City as heretofore.

By 1920 the Association had become truly national in scope and interest. Papers dealing with 10 states were published in the *Bulletin*. New Mexico attracted attention prematurely. Amarillo became of interest because of the discovery of gas in the middle of what was supposed to be the deepest geosyncline in the Mid-Continent region which was forcefully condemned by geologic thought of that time as an improbable place to find petroleum. Granite was not discovered under the gas sand until later in the year.

The subsurface stratigraphy of Oklahoma was being deciphered and Fritz Aurin showed that oil was being produced from horizons older than the "Mississippi lime." Also, the theory of origin of Mid-Continent folds by compaction and settling of shales was presented for the first time.

Consternation was aroused when E. A. Stephenson announced the rapid decline of production in the Ranger field and proved that most of the oil wells would be a financial loss.

Johan A. Udden called attention to the possibility of using the seismograph to locate buried anticlines, an idea which was made the subject of experimentation in this country in 1921 by D. W. Ohern.

### SIXTH ANNUAL MEETING, TULSA, MARCH 17-19, 1921

Officers elected:

George C. Matson, president
George Clark Gester, vice-president
Charles E. Decker, secretary-treasurer
Raymond C. Moore, editor

Among the resolutions adopted at this meeting were the publication of the *Bulletin* at regular intervals, the authorization of a salary for the editor, the appointment of a committee "to coöperate with the U. S.

Geological Survey in estimating the amount of national reserve petroleum resources and in informing the public of the seriousness of the reserve depletion."

Politics, which began with the formation of the Association in 1917, became the center of interest at this and at several subsequent meetings and has contributed largely to its interest, growth, and expansion.

Papers of timely interest dealt with: (1) the subsurface geology of Oklahoma and Kansas, proof that the Ordovician contained important reservoir rocks; (2) the origin and composition of oil shales; (3) the recognition of oil and gas production of Lower Cretaceous age in northern Louisiana; (4) the recognition of buried hills and ridges in several states as the cause of oil accumulation; and (5) diamond drilling as a means of locating anticlines. The outstanding paper of the meeting was on the paleogeography and historical geology of the Mid-Continent oil district by Alex W. McCoy.

### SEVENTH ANNUAL MEETING, OKLAHOMA CITY, MARCH 9-11, 1922

Officers elected:

W. E. Wrather, president
Max W. Ball, vice-president
Charles E. Decker, secretary-treasurer
Raymond C. Moore, editor

At the business meeting approval was given to the appointment of an advertising manager, and to the expulsion from membership by the unanimous vote of the executive committee of anyone "guilty of flagrant violation of the established principles of professional ethics." The question of a code of ethics was discussed at length. Two memorable events, besides the hectic maelstrom of the politicians who worked continuously for 48 hours, were the ballet dancing at the smoker and the story of the cockroaches by James H. Gardner, at the dinner.

A midyear meeting was held in Denver, October 26 to 28. The attendance was large. Sixty-three papers, mostly dealing with the Rocky Mountain states, were listed on the program.

J. R. Pemberton compiled the first index to the *Bulletin*, Volumes 1 to 6, inclusive, which was published in 1923.

### EIGHTH ANNUAL MEETING, SHREVEPORT, MARCH 22-24, 1923

Officers elected:

Max W. Ball, president
Frank W. DeWolf, vice-president
Charles E. Decker, secretary-treasurer
Raymond C. Moore, editor

By 1923 the membership had increased to more than 900 and the meeting was attended by several hundred. Entertainment was lavish. "Mr. Gallagher and Mr. Shean" by J. Earle Brown and J. Elmer Thomas, and "Queen Cleopatra," as impersonated by E. Russell Lloyd, will long be remembered. The program of 66 papers emphasized the geology of the Coastal Plain. It was reprinted in the *Bulletin*.

A report by the president, printed in the *Bulletin*, calls attention to the arrangements which he made to have the printing done by the University of Chicago Press with a uniform page size. The report of the treasurer showed a bank balance of $12,453.12, part of which was invested in securities during the year. A constitutional change was approved in order to make amendment possible. The salary of the secretary-treasurer was increased and traveling expenses were authorized. Honorary memberships and associate editors were authorized and approved by a mailed ballot.

An enthusiastic midyear meeting was held in Los Angeles, September 20-23. More than 400 members and guests attended and were regally entertained. The new fields of the Los Angeles Basin, those of the Santa Clara Valley and the Ventura oil field were visited. The papers described the geology of the oil fields of California. Discussion centered on the depressing effect on the oil market of the new flush production from the Los Angeles Basin.

NINTH ANNUAL MEETING, HOUSTON, MARCH 27-29, 1924

Officers elected:

James H. Gardner, president
E. G. Gaylord, vice-president
Charles E. Decker, secretary-treasurer
Raymond C. Moore, editor

About 310 members and 200 guests attended the Houston meeting. The entertainment was the most elaborate which was ever enjoyed by the Association.

The song hit, "When They Strike Oil on My Daddy's Farm," by R. B. Whitehead, will go down in the annals of the Association as the best ever presented. The program listed 91 papers, the majority being descriptions of salt domes which were collected by Wallace E. Pratt into the volume *Geology of the Salt Dome Oil Fields*, published by the Association in 1926. Three field trips to salt domes followed the meeting. A discussion of the value of micropaleontology, started in Houston by the late E. T. Dumble, and of micropetrography, started in California,

was a factor in furthering the microscopic examination of drill cuttings in all oil fields.

During the preceding year regional directors and a research committee were appointed, a detailed code of ethics prepared by Alexander Deussen and Max W. Ball was adopted, and the Association funds were invested in securities. The resources were $17,938.45, an increase of more than $15,000.00 in three years. The number of pages in the *Bulletin* for 1921 was 708; for 1924 it was 860. During this period the membership had increased from 621 to 1,080. The addresses showed the following distribution of membership: Oklahoma, 312 (Tulsa 123); Texas, 140; California, 99; Kansas, 52; Rocky Mountain states, 99; states east of the Mississippi (including some, but not all, abroad), 187. The membership had become international.

An informal banquet was held in connection with the International Petroleum Exposition in Tulsa, October 6 to 8. No papers were given. The Research Committee announced that $4,000.00 had been raised and an appropriation was made to aid in the study of source beds of petroleum under the direction of David White.

### TENTH ANNUAL MEETING, WICHITA, MARCH 26-28, 1925

Officers elected:

E. L. DeGolyer, president
R. S. McFarland, vice-president
Charles E. Decker, secretary-treasurer
Raymond C. Moore, editor

The Wichita meeting was attended by 438 members. Field trips were taken to El Dorado, to the salt mines at Lyons, and to the Russell oil field. Eighty-two papers were listed on the program, the first day being devoted to papers on Kansas. Announcement of the formation of the Pacific Section was made. Attention was called to the increasing percentage of the membership engaged in petroleum engineering. The incorporation of the Association was commenced but not completed until 1927. The *Bulletin* increased in size during 1925 to 1,319 pages, requiring binding as two volumes. Abstracts were added at the beginning of the articles. The dues were increased to $15.00 a year, effective January 1, 1926.

The inauguration of a business office with salaried, full-time employees for the Association, as authorized at the Wichita meeting, had been deferred by the Executive Committee in spite of an overwhelmingly favorable postal-card ballot in which Tulsa received the most votes as the best place for headquarters.

The first meeting of the Pacific Section was held in San Francisco November 19 and 20, about 100 members being present. A program of 19 papers was presented.

ELEVENTH ANNUAL MEETING, DALLAS, MARCH 25-27, 1926

Officers elected:

Alex W. McCoy, president
C. Rolfe McCollom, vice-president
Fritz L. Aurin, secretary-treasurer
John L. Rich, editor

The third Dallas meeting, under the direction of R. B. Whitehead, was concentrated on symposiums on the origin of oil and specialized methods for searching for and deciphering buried or obscure structural features—geophysics, micropaleontology, and core drilling. A section of paleontology was authorized and in its first meeting Henry Howe was elected chairman.

The *Bulletin* was made a monthly publication. Research was commenced by the American Petroleum Institute, and the research committee of the Association became less active. A healthy financial condition, $26,609.18 in cash and investments, showed financial stability. The Association reiterated its authorization to the Executive Committee to employ a business manager and to establish permanent headquarters. A complete change in the personnel of the officers was made for the first time since 1918.

A very successful banquet and entertainment was arranged by R. B. Whitehead.

Permanent headquarters were established by the incoming Executive Committee at Tulsa and J. P. D. Hull was appointed business manager, effective July 15. He assumed the duties of editing the *Bulletin* commencing with the August number as well as taking over the secretarial and financial details.

A joint meeting with the Western Division of the American Mining Congress, the Colorado Chapter of the American Institute of Mining and Metallurgical Engineers, and the American Silver Producers' Association, was held in Denver, September 20-24. Eight papers were presented by the Association, dealing with Cordilleran and western Mid-Continent geology. The presence of salt domes in southeastern Utah was announced and their origin became the subject of extended discussion. The Bureau of Mines oil shale plant near Rulison, Colorado, was visited.

A midyear meeting was held in New York City, November 15-17, with a program on the geology of foreign oil fields and a symposium on continental drift led by W. A. J. M. van der Gracht. A revolving publication fund was established by the New York City geologists and with its aid a volume of 240 pages, *Theory of Continental Drift*, was published by the Association in 1928.

TWELFTH ANNUAL MEETING, TULSA, MARCH 24-26, 1927

Officers elected:

G. Clark Gester, president
Luther H. White, vice-president
David Donoghue, secretary-treasurer
John L. Rich, editor

The third Tulsa meeting was attended by 769 members and 1,058 guests. Only 1,500 programs were printed and the supply was exhausted the second day of the meeting. Three banquets were held simultaneously and the Akdar Theatre was filled to overflowing for the entertainment "The Rockhound Review," after the banquets. A meeting of the paleontologists and microscopists was held at the same time and the Society of Economic Paleontologists and Mineralogists was organized. Field trips following the meeting were conducted to Seminole, the Arbuckle Mountains, and to a special entertainment at the 101 Ranch near Ponca City.

A symposium on the relation of petroleum accumulation to structure was the central theme of the meeting. The papers will be printed in 1929 in two volumes entitled: *Structure of Typical American Oil Fields*. The publication fund established at the New York meeting defrayed part of the cost of publication. Progress of the business manager was reported.

On account of the establishment of headquarters, the Association approved a change in the constitution to have the titles of officers read: president, first vice-president, second vice-president in charge of finances, and third vice-president in charge of editorial work. Ballots for the election of officers were authorized to be deposited in locked ballot boxes at the annual meeting. The Executive Committee was empowered to advance to active membership the associates who were qualified, and also to drop from membership any member who failed to pay the regular annual dues for a period of one year. A new General Business Committee elected in local districts, each delegate to hold office for a term of three years, and one-third of the members retiring annually, was provided to

replace the temporary committees of the past and to act as council for the Association and as an advisory board to the Executive Committee.

THIRTEENTH ANNUAL MEETING, CALIFORNIA, MARCH 21-25, 1928

Officers elected:

R. S. McFarland, president
J. E. Elliott, first vice-president
David Donoghue, second vice-president
John L. Rich, third vice-president

The first annual meeting to be held in California was opened in San Francisco and concluded in Los Angeles. Several field trips were arranged to visit the oil fields. The program listed 31 papers and that of the Society of Economic Paleontologists and Mineralogists, 9 papers.

Announcement was made of arrangements to print the *Bulletin* in Tulsa and of the publication of an index to the first ten volumes prepared by Daisy W. Heath.

The membership of 1,952 was distributed in 41 states and 29 foreign countries. It is notable that the new West Texas oil fields have caused a larger increase in membership in Texas (575) than in Oklahoma (455) in contrast with the figures compiled in 1924. California is third with 238 members. The foreign membership totals 170.

Reauthorization of life membership was made on the payment of $300.00. The fiscal year was officially changed to the calendar year.

RECAPITULATION

This Association was organized in Tulsa in 1917 by the petroleum geologists working in the Southwest, and for the first year it was known as the Southwestern Association of Petroleum Geologists. It has been a stimulant to the evolution of geologic thought in North America, not only in regard to petroleum, but to the entire field of geology including paleontology and petrography. It is the largest and most influential geological society in the world and its *Bulletin* is finding a place in libraries throughout the world which have ruled against the inclusion of periodicals not dealing with "pure" science.

The growth from 94 members in 1917 to more than 2,000 at the end of 1928 and the steady rate of increase of membership indicate that this young society has a future more brilliant than the past and will continue to grow as long as petroleum and its derivatives are required as fuel.

# GEOLOGICAL NOTES

## SUBSURFACE CORRELATION METHODS IN THE WEST TEXAS PERMIAN BASIN

Little has been written of the methods of subsurface correlation employed by geologists in the West Texas Permian basin, although the province is notable for its present and potential oil production, and is most decidedly a region in which the geologist relies upon data of wells already drilled in order to locate new tests. Subsurface work is so widely pursued, and the importance of studying collections of formation samples taken at regular and close intervals is so generally recognized that scarcely a wildcat well is now drilled without special instuctions being given that samples be systematically saved. The collection of these samples has become a duty of company scouts or specially designated "sample grabbers" who do little else. In order that those of the oil industry in West Texas other than geologists may know why such importance is attached to samples, and that geologists in other districts may know something of subsurface methods used in West Texas, the following brief article is written. The writer is indebted to John Emery Adams of the subsurface laboratory of The California Company, with whom he was formerly associated, for suggestions and material.

The formations penetrated in drilling wells in the Permian basin are shown in the accompanying generalized stratigraphic table (Fig. 1). In the Cretaceous formations only are recognizable, diagnostic fossils commonly found. Since the Triassic, Cretaceous, and younger beds do not rest conformably on the Permian, it was early recognized that determinations of subsurface structure should be based on horizons within the Permian. The top of the "Big lime" and the top of the Delaware Mountain formation, commonly referred to as the "Delaware sand," were selected as most satisfactory, both because they would best show the structure of the principal productive zones, and because they were most easily determined. The top of the salt beds was widely used at first for general upper-hole correlation, but more extensive drilling has shown that it is dependable in local areas only. Other horizons

| AGE | | THICKNESS FEET | DESCRIPTION |
|---|---|---|---|
| QUATERNARY & TERTIARY | | 0-500 | SURFACE GRAVELS, SANDS, CLAYS AND CALICHE. THICKEST DEVELOPMENT IN REEVES COUNTY AND ON HIGH PLAINS |
| CRETACEOUS | | 0-700+ | LIMESTONE, WITH A BASAL SANDSTONE. A FEW SHALE BEDS IN BOTH. BEST DEVELOPED IN THE EDWARDS PLATEAU REGION WHERE IT CROPS OUT |
| TRIASSIC | | 0-1700 | RED AND GRAY SHALE, RED AND GRAY SANDSTONE AND CONGLOMERATE EXPOSED IN A BELT ALONG THE EAST MARGIN OF THE BASIN, AND IN THE PECOS RIVER VALLEY. REPRESENTED IN THE UPPER PART OF THE HOLE OF WELLS IN MOST OF PERMIAN BASIN. |
| PERMIAN | EVAPORITE & RED BED SERIES | 500-4000 | PRINCIPALLY ANHYDRITE, SALT, RED SHALES, RED, GRAY AND BUFF SANDSTONES AND A LITTLE DOLOMITE AND GRAY SHALE. IN THE CASTILE BASIN A FORMATION FROM 1000-1500 FEET THICK OF SALT AND CALCITE-BANDED ANHYDRITE TENTATIVELY CALLED THE LOWER CASTILE SEPARATES THE YOUNGER EVAPORITE AND RED BED SERIES FROM THE DELAWARE MOUNTAIN FORMATION |
| PERMIAN | "BIG LIME" | | DOLOMITE, WITH VARYING MINOR PROPORTIONS OF ANHYDRITE, RED AND GRAY SHALE, AND SANDSTONE, ESPECIALLY NEAR THE TOP. |
| PERMIAN | DELAWARE MOUNTAIN | | FINE GRAY SANDSTONE WITH SOME BLACK SHALE AND A LITTLE LIMESTONE. |

Fig. 1. Table of formations of the West Texas Permian basin.

have been found of local value, such as the Yates sand,[1] the base of the salt, and the top of the Lower Castile.

The Delaware sand is encountered beneath the Lower Castile member of the evaporite (anhydrite and salt) and Red-beds series in the western part of the Permian basin, principally in Reeves and Loving counties, and in parts of Eddy, Lea, Winkler, Pecos, Culberson, and Ward counties. As the top of the Delaware sand is a readily recogniz-

[1]Discovered by John Emery Adams and described and named by the writer and Mr. Adams. See G. C. Gester and H. J. Hawley, "The Yates Field, Pecos County, Texas," *Structure of Typical American Oil Fields*, Vol. 2, Amer. Assoc. Petrol. Geol. (in preparation).

able horizon, it will not be discussed further. The "Big lime" is not a recognizable part of the section in the region in which the Delaware sand is found, and its correlation with that section is a frequently debated subject among West Texas geologists.

The name "Big lime" is applied to the dolomite or dolomitic limestone which is encountered below the evaporite and Red-bed series in most of the basin. It seems probable that in parts of the basin an unconformity separates it from the overlying beds, but in other parts the evidence strongly opposes the presence of an unconformity. The exact stratigraphic position of the "Big lime" in the geologic column is not settled yet, and there is evidence that its top is not of the same age throughout the basin. Megascopic and microscopic fossils are found in some cores from the "Big lime" and in thin sections made from drill cuttings. They are commonly very poorly preserved, and where they are specifically determinable, type material is not available for comparison. In spite of the unsettled questions relating to the "Big lime," the top of this formation in wells is selected as a point from which to calculate structure.

The character of the top of the "Big lime" is quite different in various parts of the basin, as is shown in Figure 2. In some places there is a gradation of hundreds of feet through which occur dolomite, anhydrite, red and non-red sandstone and shale; in other places the break is abrupt. It is because the top of the "Big lime" is so poorly defined in many areas that very many of the "lime tops" first reported are later found to be erroneous. In working each part of the basin it is necessary first to determine what point in the stratigraphic column between the known "Big lime" and the overlying beds is constant laterally in that area. This must be done by correlation, best accomplished with carefully prepared, percentage sample logs. In some areas this point is the first well-defined dolomite break; in others it is the base of the main anhydrite; and in still others it is a thin sandstone and dolomite zone overlying a bentonite. When this point has been determined, it is generally possible to recognize it in adjacent wells. As different geologists ordinarily choose different points, the data of one may run higher or lower than the data of another, although both will refer to their points as the top of the "Big lime." In some areas, notably Lea County, New Mexico, it is essential that the geologist work out the history of deposition in determining the correlations he will adopt, and fit the lithologic sequence into the scheme of events.

It is in the attempt to define points at the top of the "Big lime" that its upper part has been divided into members, based on color, the

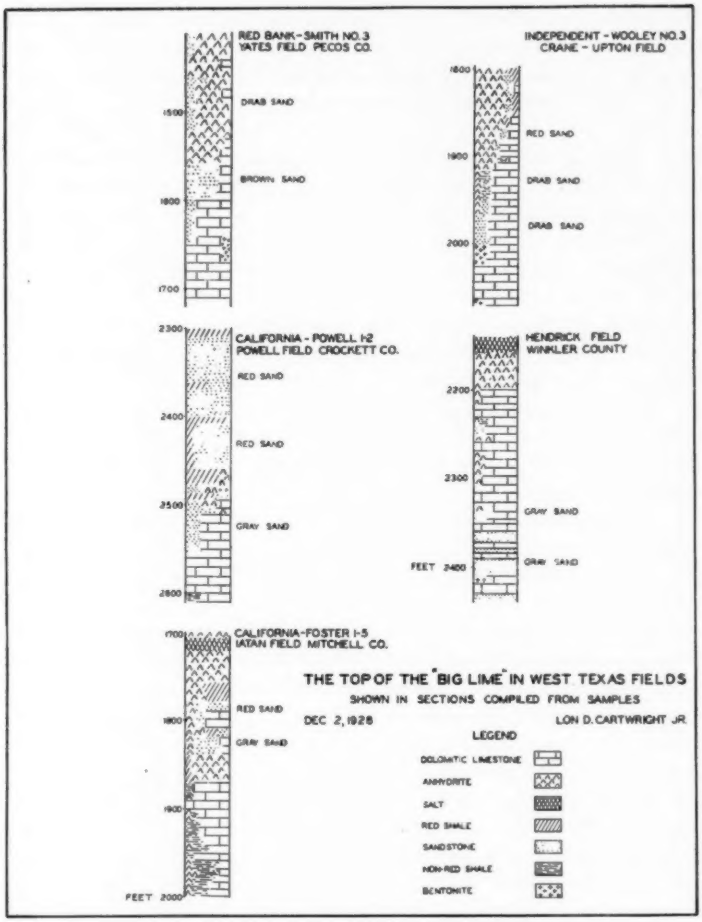


Fig. 2

presence or absence of anhydrite, sandstone, or bentonite. This has led to the use of the terms "Brown lime" (referring to a member that may possibly better be considered a part of the evaporite column), "Gray lime," "White lime," "Sandy lime," and "Pure lime," depending upon the features to which the geologist assigns correlative value. Oölitic,

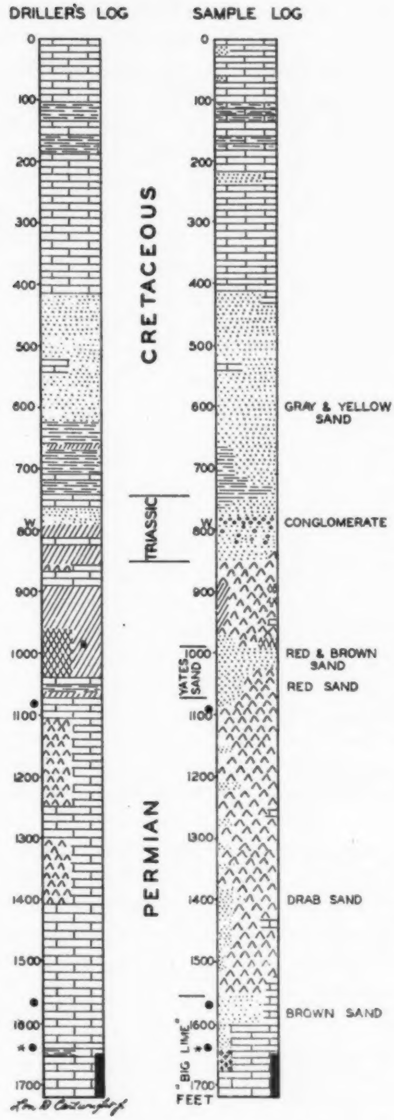


Fig. 3. Log of Yates field well as reported by driller and as taken from samples.

lignitic, and cherty zones have been recognized as of local value, more as a check than as anything else. Oil-, gas-, and water-bearing zones are extensively used, although field wells close together show that these zones may vary in stratigraphic position.

When the nature of the contact of the "Big lime" with the overlying beds is understood, the need for samples becomes evident. The principal difficulties with using drillers' logs are: (1) most drillers do not properly differentiate the rocks they drill, especially anhydrite, limestone, and dolomite; (2) their logs are too generalized; and (3) they may not record small amounts of some rock, the presence of which in the particular section may be critical. A comparison of a graphic log made from sample examination with a graphic log prepared from the driller's log on the same well (Fig. 3) shows that the true idea of the formations penetrated is not afforded by the driller's log, and that the features upon which correlations might be based are shown very poorly, if at all. In the driller's log in this figure, it may be observed that the gravel at 800 feet is reported as limestone; the upper anhydrite which carries a little red shale, salt, and dolomite, is reported as being principally red shale and salt; and the sandstone at 1,000 feet, which is a readily recognizable formation in the Yates field, is not reported at all. Most important, the driller's log does not correctly indicate the top of the "Big lime," which may be located from it 125 feet higher than it really is.

Many operators try to save samples at the top of the "Big lime" only. In doing this they may take too few, thus failing to obtain the data necessary for locating the top accurately. Recent work in the Yates field has shown that it is possible to distinguish upper hole horizons when sufficient samples are available, and the evidence of these horizons may become of great importance, many times repaying the trivial cost of collecting.

The writer believes that, although the subsurface stratigraphy of the West Texas Permian basin is a very complicated problem, if good samples are saved from a sufficient number of wells, both field and wildcat, and if geologists coöperate properly in their study and interpretation, it will be possible eventually to interpret most of the intricate details now so puzzling.

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CARLSBAD, NEW MEXICO
December 14, 1928

## A SECOND RECORD OF HAUERITE ASSOCIATED WITH GULF COAST SALT DOMES[1]

In 1926 Wolf[2] described and pictured several crystals and chunks of hauerite ($MnS_2$) which were found in the cap rock and anhydrite of the Big Hill salt dome, Matagorda County, Texas. As far as the present writer has been able to determine, no other discoveries of hauerite have been reported from the Gulf Coast salt domes.

Hauerite has recently been observed in a core from a depth of 2,572 feet in the Gulf Production Company's George E. Smith No. 8 on High Island salt dome in Galveston County, Texas. The core consists chiefly of crystals of anhydrite, whose average diameter is slightly less than 1 millimeter. The core is massive except for a few voids into which extend euhedral anhydrite crystals and a few crystals of sulphur. Scattered through the anhydrite are many subhedral crystals of hauerite. The largest crystal of hauerite observed was slightly more than 5 millimeters in length. These crystals, as far as growth would allow, have tended toward octahedrons. Only a few suggest cube truncations. Several are little more than hauerite cementing material for the anhydrite. This is evidenced by the euhedral crystals of anhydrite completely enclosed in hauerite, as well as euhedral terminations partly embedded. If the massive anhydrite (there is much evidence to support this contention) has its origin in the leaching of the salt mass with the consequent formation of an anhydrite sand, which, previous to the leaching, was finely disseminated through the salt, and a later consolidation into massive anhydrite, it seems likely that these hauerite crystals were formed during the transition period between anhydrite sand and massive anhydrite.

MARCUS A. HANNA

HOUSTON, TEXAS
December 12, 1928

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## ORIGIN OF THE SANGRE DE CRISTO CONGLOMERATES, COLORADO

In the symposium, *Theory of Continental Drift*, published by the Association last year, several statements were given as to the origin of the Permo-Pennsylvanian conglomerates of Colorado, particular reference being made to those of the Sangre de Cristo region. Wegener

[1]Published with permission of the Gulf Production Company.

[2]Albert G. Wolf, "Hauerite in a Salt Dome Cap Rock," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 5 (May, 1926), pp. 531-32.

(p. 100) makes a plea for American geologists to study these conglomerates.

The writer spent most of the summer of 1927 making a study of these and associated deposits for The Texas Production Company. A general study was made of the entire area, detailed sections were measured, with an intensive search for fossils in all beds. This was followed by laboratory work on the material collected.

From this work several suggestions were obtained as to the origin of the formation. These may be briefly summarized as follows.

The sediments were deposited along, and close to, the shores of two land masses, one of which occupied approximately the area of the present Wet Mountains, and the other, a much larger mass, extended west and northwest from approximately the middle of the present San Luis Valley. The deposits represented are both marine and subaerial, and include littoral, non-littoral but shallow-water marine, delta, alluvial fan, possibly some flood-plain, and some swamp deposits. In other words they represent the material which was rapidly eroded from high lands close to the sea and was deposited near by as a series of great alluvial fans which projected from the base of the mountains, in some places out into the sea. Some of the larger streams built small flood plains and large deltas. The waves and ocean currents partly re-worked and deposited materials carried into the sea and deposited along its shores. Locally, for example, in the area west of Silver Cliff, there is a suggestion of active wave erosion against great rocky cliffs. Small swamps or marshes developed in some basins between alluvial fans and coastwise deposits. The general picture is one of rapid erosion by steep and possibly torrential streams, the material so obtained being quickly deposited close to the source of supply. There is no evidence, or even suggestion, of glacial action (except, possibly, the great size of some of the fragments).

The coarse, sub-angular character and large size of some of the fragments can easily be explained as the work of streams or waves. Almost identical material can be seen at the present time being formed and deposited by the mountain streams of the area in the great alluvial fans which they are now building.[1]

J. Harlan Johnson

Golden, Colorado
January 11, 1929

[1] A more detailed discussion of the paleogeography of the area and the origin of these sediments may be found in a paper by the writer to be published in the near future by the Colorado Scientific Society under the title "Contributions to the Geology of the Sangre de Cristo Mountains of Colorado."

# DISCUSSION

## A CLASSIFICATION OF LIMESTONE RESERVOIRS

In the December (1928) number of the *Bulletin*, I notice the very interesting classification of limestone reservoirs by W. V. Howard, pages 1153-61, and that he lays great stress upon the reservoirs which lie just below a disconformity and are due to subaerial erosion. In this conclusion I agree with him and I wish to call attention to the fact that, with such conditions, the water associated with the oil may well be that which comes in and fills the caves when the land once more sinks and the water level rises relatively. It will thus be land water rather than sea water, or if it is sea water, it will be sea water of the date of the submergence and not that of the date of the original limestone. I had already called attention to this fact in my paper "Calcium Chloride Waters, Connate and Diagenetic" in the *Bulletin*, Vol. 11, No. 12 (December, 1927). I think careful appreciation of this fact will explain some seeming peculiarities in the waters of certain districts, as I have suggested on pages 1302-03.

ALFRED C. LANE

TUFTS COLLEGE, MASSACHUSETTS
December 20, 1928

## DIFFERENTIAL COMPACTION

The acting editor is indebted to Sidney Powers for directing attention to the following error and omissions in the article on "Studies in Differential Compaction" by C. M. Nevin and R. E. Sherrill in the January *Bulletin:*

Page 5, line 1: the word "truck" should be *tank*.

Plate 1, Figure 1: the letter *A* should appear at side of figure at contact of black and light gray horizons.

Plate 1, Figure 2: the two black horizons should be labelled *A* and *B*, *B* being the higher and marked "Sand."

Plate 1, Figure 3, and Plate 2, Figures 4 and 5: the five black horizons shown should be labelled *A*, *B*, *C*, *D*, and *E*, beginning with the bottom black horizon; in each figure the horizon marked "Sand" is horizon *B*.

Plate 3, Figure 6: of the two broken black lines extending up and over the dome, the lower should be labelled *A* and the higher, *B*. The upper surface of the horizon marked "Sand" should be labelled *C*.

Plate 3, Figure 7: the two thin black horizons at the base of the horizons marked "Sand" are *A* for the lower and *B* for the higher.

Plate 3, Figure 8: the contact of the black and gray horizons at the middle of the section is *A*.

Plate 4, Figures 9 and 10: the five black horizons extending all the way across the sections are *A*, *B*, *C*, *D*, *E*, respectively, from bottom upward.

J. P. D. H.

# REVIEWS AND NEW PUBLICATIONS

"The Geology of the Silurian Rocks of Northern Indiana." By EDGAR R. CUMINGS and ROBERT R. SHROCK. *The Department of Conservation, Indiana, Publication No. 75* (1928), 226 pp., 45 figs., 3 maps and charts, and 33 figs. of fossil graptolites.

This excellent work by Cumings and Shrock gives to geologists a picture of the Silurian of northern Indiana, and, by extension, Illinois, Michigan, and Wisconsin, which has not heretofore been available. The book may be considered to be divided into seven parts: review of the literature, physiography, stratigraphy, structure, paleogeography, economic geology, and paleontology.

The review of the literature (pp. 11-26) seems complete, at least with respect to the essential papers. On later pages in the book is given a rather complete bibliography dealing with the northern Indiana Silurian.

The part devoted to physiography (pp. 27-52) describes the general physiography and gives the physiographic history. In the "Wabash Trough," a channel or sluiceway developed by the discharge of the glacial waters toward the south during the Ice Age, are dome-shaped hills which are described as "klintar" (singular klint), a name imported from the Island of Gotland in the Baltic Sea, where hills of similar origin are known by that name. These hills are shown to be the cores of Silurian coral reefs which, together with some of their marginal rocks, have persisted because of their relative resistance compared with the rocks around them.

In the section on stratigraphy (pp. 53-135) there is given the geologic section which, from the base upward, consists of the Mississinewa shale, the Liston Creek formation, the Huntington dolomite, the New Corydon limestone, the Kokomo limestone, and the Kenneth limestone, the section having a thickness of approximately 500 feet. Each of the formations is described in detail: the thickness, distribution, lithology, variations, and faunal characteristics. The strata belong to the Niagaran and Cayugan divisions of the Silurian, the Mississinewa shale, Liston Creek formation, Huntington limestone, and New Corydon limestone being Niagaran and the Kokomo and Kenneth limestones being Cayugan.

In the section on structure the broader structural relations are treated and attention is called to a local warping near Kentland. The most interesting features of the structure are those connected with the coral reefs. These have been known for many years and, because of the rather intensive quaquaversal relations at their margins, most geologists have attempted to relate them to locally applied diastrophism. Cumings and Shrock have found the evidence proving that the central cores of the previously supposed uplifts are irregular masses of rock without stratification, which owe their origin to reef-building organisms. Marginal to the central cores are stratified rocks with outward dips ranging from 4° or 5° to as much as 65°. There is some faulting connected

with the reef rocks and also the inclined marginal beds. More than seventy reefs are known from the Silurian of northern Indiana and some of the better known are described in detail.

The section on paleogeography is short (pp. 164-67), and there is given a paleogeographic map of middle Niagaran time, the map covering the entire Michigan basin area. The map shows the extent of the middle Niagaran sea, the present exposures of middle Niagaran strata, and the general locations of the coral reefs.

The section on economic geology discusses the uses made of the different rocks of the Silurian formations. The Mississinewa shale is used in the manufacture of mineral wool. The different limestones are quarried for use in blast furnaces and building stone, the latter not so important as in former years. Limestone is also quarried for the burning of lime, an industry which is not so great as in earlier years. Many quarries are described in greater or less detail.

The section on paleontology gives a general discussion of the faunas, and a faunal chart in which the species and their vertical ranges are listed. The last 25 pages contain descriptions of 28 forms of a new graptolite fauna. Ten of these forms are new to science. This last part of the paper is entirely the work of the junior author and has previously been published in the *American Journal of Science*, Vol. 16 (1928), pp. 8-38.

This most recent paper on the Silurian of northern Indiana is of exceptional merit. It is valuable equally to the paleontologist, stratigrapher, sedimentationist, and economic geologist. The sections dealing with the reef structures should be studied in detail by all geologists who are concerned with sedimentary rocks, as similar structures are likely to occur in all marine deposits from the Lower Cambrian to the Present, and it may be that some of the alga formations of the pre-Cambrian are of dimensions sufficiently great to produce similar results.

W. H. TWENHOFEL

THE UNIVERSITY OF WISCONSIN
MADISON
December 13, 1928

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*Guide des Excursions Deuxime Reunion en Roumanie, Association pour l'Avancement de la Géologie des Carpates* (Bucarest, 1927). By L. MRAZEC, G. MACOVEI, AND OTHERS. Vol. 1, text, 384 pp; Vol. 2, illustrations, 17 plates comprising maps and sections.

The guide comprises: L. Mrazec and E. Jekelius, Review of the Neogene Basin of Transylvania and its Deposits of Gas, 22 pages; G. Macovei, Review of the Geology of the Eastern Carpathians, 119 pages; D. M. Preda, Geology of the Valley of the Teleajen in the Foothill Region of the Carpathians, 28 pages; L. Mrazec and I. Atanasiu, the Diapire Anticline, Moreni-Gura Ocnitei, 23 pages; O. Pratescu, Geology of the Valley of the Prahova between Câmpina and Comarnic, 44 pages; G. Macovei and I. Atanasiu, The Interior Zone of the Flysch in the Area of the Headwaters of the Prahova and the Upper Basin of the Olt, 16 pages; G. Macovei and I. Atanasiu, the Volcanic

Chain, Calimani-Harghita, 7 pages; the Crystalline Massif and the Mesozoic Deposits of the Hâghimas Mountains in Eastern Transylvania, 32 pages; G. Macovei and I. Atanasiu, the Interior Zone of the Flysch in the Area of the Valleys of the Bistriciora and the Bicaz, 19 pages; S. Athanasiu, G. Macovei, and I. Atanasiu, the Marginal Zone of the Flysch in the Lower Part of the Bistrita, 38 pages; I. Simonescu, Review of the Geology of Dobrogea, 26 pages.

This guide is a notable contribution to the literature on the geology of the Roumanian Carpathians. It is more than a mere guide to the excursions. It is a well-written review of the geology of the Roumanian Carpathians. It is valuable also for its references to the literature on the areas covered.

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"Geologische Studien im Westlichen Serbien" (Geological Studies in Western Serbia). By LUDWIG VON LÓCZY, SR. *Ergebnisse der von der Orientcommission der Ungarischen Akademie der Wissenschaft Organisierten Balkanforschungen*, II Bd., Geologie (Berlin and Leipzig, 1924). In German. 146 pp., 4 plates.

When Serbia, Montenegro, and Albania had been occupied by the troops of the Central Powers during the recent war, the Hungarian Academy of Science sent out expeditions to study the geology, geography, zoölogy, botany, archaeology, art, and history of those countries. The present volume gives Prof. Lóczy's posthumous account of the results of the work of himself and of his assistants in western Serbia during 1916-18.

The volume covers: the Drina and Drina valley, general morphology of western Serbia, general geology of western Serbia; Paleozoic crystalline schists, Triassic deposits, the ophite district of western Serbia, the Jurassic system, the Cretaceous formations, the Cenozoic formation, the Pleistocene and Recent formations, volcanics; and a review of the tectonics and paleogeography.

The text is illustrated with a colored geologic map on the scale of 1:200,000 and by two large sheets of structure sections.

The report summarizes the data of the literature on the area and of a large amount of original work. It should be a valuable reference on the geology of western Serbia for a long time.

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*Streifzüge eines Geologen im Gebiet der Goajira-Indianer, Kolumbien*. By OTTO STUTZER. Dietrich Reimer-Ernst Vohsen (Berlin, 1927). 154 pp., 67 photos, 1 map.

This book deals mainly with the description of the author's travels in the Goajira peninsula from February to May, 1925. The geological information

furnished in the first 100 pages of the book is rather scanty, but a good general idea of structural conditions is given in a separate chapter of 3½ pages.

The mountains of the East Goajira consist of eruptive rocks and schists. In some parts the crystalline ground mass is overlain unconformably by conglomerate, which in turn is overlain by sandstone, and this by limestone. The limestone seems to belong to the Villeta formation (the upper part of the Lower Cretaceous), and the sandstone and conglomerate to the lower part of the Lower Cretaceous, or Giron of Hettner. Cretaceous formations younger than the Villeta were not found, nor were any layers of the Guaduas (Eocene) formation found. The Villeta formation is unconformably overlain by young marine layers of shales, limestone, and sandstone, probably of Pliocene age.

The strike of the mountains is generally in the same northeasterly direction as the peninsula itself. The elevation of the mountains took place after the Villeta formation was deposited. If the coast line from Cabo de Vela is continued southward inland, then the Goajira peninsula is divided into halves which are entirely different. The east half is mountainous, with crystalline rocks, and the west half is a plain. It is probable that this is a fault line with the downthrow on the west. North of the Montes de Oca occurs another east-west fault with downthrow on the north.

The only mineral which is exploited at present is salt, which is won from salines on the west coast of the peninsula. Coal, phosphates, gold, copper, and chromite have been reported, but none found in paying quantities. The author mentions in several places that he does not discuss the petroleum possibilities, although they are more interesting to him and to others. The reason, which he does not give, is obvious, since the trip was made as a Colombian government official and the government of Colombia treats all the reports made by its officials referring to the occurrence of petroleum as confidential. Only the highest officials are permitted to read them, although such investigations are paid for by part of the taxes levied on the whole people. Comment thereon is unnecessary. The existence of the Villeta and Pliocene formations on the Goajira peninsula makes it evident that geological examination for petroleum would be justified. The photographs illustrating the book are excellent reproductions and give a very good idea of the people and landscape. The map has many faults, as the author acknowledges, but it is still the best map in existence.

In addition, the author furnishes very useful and interesting information concerning boundary questions, climatic and sanitary conditions, plants and animals, an excellent chapter on surface and underground water conditions, economic and transportation conditions, the Capuzin Monks and their missions, advice to travellers, and full information regarding the Goajira Indians. A reference list of six Spanish, two English, two German, and one Swedish book is given. The reviewer does not know of any additional books covering the geology of this area, except the annual reports of the Ministerios del Gobierno of Colombia, some of which contain information of interest to geologists.

F. O. Martin

Los Angeles, California
January 4, 1929

## RECENT PUBLICATIONS

### GENERAL

"Faults Undiscovered on the Ground Revealed by Aerial Maps," by Leon T. Eliel. *Oil Field Engineering* (Jan. 1, 1929), pp. 24-27, and 64, illustrated.

"The Lower Cretaceous or Comanche Series," by T. W. Stanton. *American Journal of Science* (5), Vol. 16, No. 95 (Nov., 1928), pp. 399-409.

### CALIFORNIA

"Long Beach Oil Field," by D. C. Roberts. *Summary of Operations, California Oil Fields*, Vol. 13, No. 11 (May, 1928), pp. 1-20, plates 1-7.

### EUROPE

The following numbers of *Die Kriegsschauplätze, 1914-18* (Theaters of the War), geologically portrayed under the editorship of J. Wilser (Freiburg), have been issued by the press of Gebrüder Borntraeger (Berlin, 1928):

Heft 8. "Flanders," by Wilifried von Seidlitz. 82 pp., 12 illus. Price, 10.40 M.

Heft 9. "Ostbaltikum" (Teil 1), by H. Scupin. Algonkian, Paleozoic, and Mesozoic. 270 pp., 18 illus. Price, 36 M.

Heft 10, Teil 1. "Ostbaltikum" (Teil 2), by Ernst Kraus. Tertiary and Quaternary. 142 pp., 22 illus. Price, 16.80 M.

### MEXICO

*Boletin y Agenda*, Juan Korzujin, managing director, Centro Geofisico and the Association of Geophysics (Mexico, D. F., Nov., 1928), Vol. 1, No. 1, pp. 1-16. Price, $2.50.

### WYOMING

"The Pumpkin Buttes Coal Field, Wyoming," by C. H. Wegemann, R. W. Howell, and C. E. Dobbin. *U. S. Geol. Survey Bull. 806-A* (Washington, D. C., Oct. 8, 1928), 14 pp. 5 plates, 1 fig.

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## TECHNICAL PERIODICALS

The following periodicals have been added to the list of publications regularly received at Association headquarters:

*Boletin y Agenda de Centro Geofisico y de la Asociacion de Geofisicos en Mexico* (Mexico, D. F.)

*American Journal of Science* (New Haven)

# THE ASSOCIATION ROUND TABLE

## MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

### FOR ACTIVE MEMBERSHIP

Lorin A. Cranson, Taft, Calif.
R. G. Whealton, F. C. Merritt, Bartlett W. Gillespie
James Hopkins, New York, N. Y.
Harold E. Boyd, V. R. Garfias, L. C. Snider
Ernst Joseph Lehner, Pointe-a-Pierre, Trinidad, B. W. I.
Axel A. Olsson, C. R. McCollom, Desaix B. Myers
Carl A. McAdams, Wichita, Kan.
Louis Roark, T. E. Weirich, A. I. Levorsen
Waldo W. Waring, Tampico, Mexico
Carroll H. Wegemann, Oliver B. Knight, James B. Dorr

### FOR ASSOCIATE MEMBERSHIP

Charles T. Jones, Tulsa, Okla.
Kurt H. de Coussér, Thomas W. Leach, E. N. Murphy
George Roger Pinkley, Tulsa, Okla.
Virgil O. Wood, E. O. Markham, E. L. Roark
Paul M. Stebbins, Wichita, Kan.
L. J. Youngs, Paul A. Whitney, J. L. Garlough

### FOR TRANSFER TO ACTIVE MEMBERSHIP

Leslie M. Clark, Los Angeles, Calif.
E. F. Davis, Eric K. Craig, M. G. Edwards
James N. Hockman, San Angelo, Tex.
D. D. Christner, D. E. Lounsbery, Paul J. McIntyre
Paul F. Morse, Houston, Tex.
Lloyd North, F. W. DeWolf, Donald C. Barton

## STRUCTURE OF TYPICAL AMERICAN OIL FIELDS

*Structure of Typical American Oil Fields*, Volume 1, the Association's new book embodying the papers of the special Tulsa (1927) program, is now

ready for distribution. This book (in two volumes) has been described as the most useful publication of the Association outside of the *Bulletin* itself. Its preparation has been delayed in order to include all the available manuscripts listed in the symposium on the relation of oil accumulation to structure. The larger part of the work is entirely new material composed of recent manuscripts never before published. In Volume 1, thirty-nine authors describe typical fields in thirteen states. There are 510 pages with 194 illustrations. The volume is bound in blue cloth with gilt title, in standard size of 6 x 9 inches,—in style similar to the other special publications of the Association. The published price is $5.00, but members are entitled to purchase copies at the special price of $4.00, postpaid. As the expense of this work is largely borne by our special publication fund, which fully serves the useful purpose for which it was established only if the books it makes possible are sold promptly so that the funds involved are quickly paid back into the treasury, it is to the advantage of Association members to order their copies early so as to maintain the continuation of special low prices to members.

Volume 2 is almost complete and ready for the printer. The last manuscript is being written. It will contain more than 600 pages illustrated as profusely as Volume 1. It will appear this year.

Members ordering Volume 1 at the present special price of $4.00 will be helping to maintain the Revolving Publication Fund for future special books outside the *Bulletin*. Send a check for $4.00 to Association Headquarters, Box 1852, Tulsa, Oklahoma.

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## FORT WORTH MEETING, MARCH 21-23, 1929

*Reservations*.—B. E. Thompson, chairman of the arrangements committee, Gulf Production Company, Fort Worth, Texas, announces that plans for the 14th annual convention of the Association, which will be held at Fort Worth, Texas, March 21, 22, and 23, are rapidly approaching realization. At The Texas Hotel, convention headquarters, the entire fourteenth floor, including the Crystal bail room, the Blue Bonnet court, and the Cactus room, has been reserved for the occasion and is being equipped with loud speakers. In addition to the facilities at the headquarters hotel, rooms are being reserved at the Worth, Metropolitan, Westbrook, Commercial, and others. Notices in regard to room reservations have already been sent out under the direction of Ford Bradish, chairman of the publicity committee, 1205 W. T. Waggoner Building, Fort Worth, Texas. Members who have not arranged for reservations should do so without further delay.

*Technical program*.—R. A. Liddle, chairman of the program committee, Box 1007, Fort Worth, announces a varied selection of papers in addition to the symposium on the stratigraphy of the Permian basin of southwestern United States under the chairmanship of Alex W. McCoy. Papers will be presented on geophysics, crooked holes, aerial photography, new fields, foreign production and U. S. market, discoveries in Atlantic and Gulf Coastal plains, tectonics, salt domes, and other subiects.

J. Elmer Thomas, general chairman, 602 Fort Worth Club Building, makes urgent request that authors submit their papers to Mr. Liddle immediately if they have not already done so, in order that the committee may provide mimeographed copies to be used in the preparation of discussions in advance of the meeting. The provision for prepared discussions, as well as impromptu discussion, is a feature which the Fort Worth committee is especially desirous of making a success. Only thus can the greatest amount of information on any subject be elicited at the meeting.

*Railroad rates.*—Reduced fares on the basis of fare and one-half and also fare and three-fifths for the round trip, on the identification certificate plan, have been authorized by the railroads. These fares will apply only upon presentation to the ticket agent of the round-trip identification certificate which will soon be sent every member from A. A. P. G. headquarters office at Tulsa. The certificates will be available only to members and dependent members of their families. It will be necessary, when purchasing round-trip tickets, to indicate to ticket agents which class of tickets is desired: (1) one and one-half fare at regular time limit, or (2) one and three-fifths fare with limit of thirty days from date of sale. THIS IS IMPORTANT: IDENTIFICATION CERTIFICATE MUST BE PRESENTED TO TICKET AGENT; THE ROUND-TRIP TICKET MUST BE PURCHASED AT BEGINNING OF THE TRIP; RETURN PORTIONS OF TICKETS MUST BE VALIDATED BY CITY TICKET AGENT AT FORT WORTH. Certificates and full information will be mailed all members on March 1. When granting special reduced rates, the railroads have a right to expect that all members attending the convention will avail themselves of the special privilege.

*Paleontologists.*—Gayle Scott, chairman, Texas Christian University, Fort Worth, has announced that the Society of Economic Paleontologists and Mineralogists will hold its meetings on March 22 and 23. These meetings will be held on the fourteenth floor of The Texas Hotel, concurrently with the sessions of the A. A. P. G. Announcements have already been sent to the paleontologists.

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## GENERAL BUSINESS COMMITTEE

The Executive Committee met at Tulsa, Oklahoma, January 19, 1929, with the following members present: R. S. McFarland, president. David Donoghue, 2nd vice-president, and John L. Rich, 3rd vice-president The Committee accepted and approved the district elections of new representatives on the general business committee of the Association. It announced the creation of the Abilene district, Texas, in response to the request of members in that area. The composition of the general business committee for the Fort Worth meeting in March, 1929, is shown on pp. 190-91. The terms of the representatives continue until the annual meeting of the years shown in parentheses after their names. If any district fails to elect a representative, the president will appoint a representative at least thirty days before the annual meeting.

Any member of the Association wishing to bring new business before the Association should present it to his district representative, who will lay it before the business committee at the annual meeting.

GENERAL BUSINESS COMMITTEE, MARCH, 1929

C. R. McCollom, *Chairman*

| | |
|---|---|
| *A. A. P. G. Officers* | |
| President | R. S. McFarland, Box 1501, Tulsa, Okla. |
| Past-President | G. C. Gester, 1112 Standard Oil Bldg., San Francisco, Calif. |
| 1st Vice-President | J. E. Elliott, 850 Subway Terminal Bldg., Los Angeles, Calif. |
| 2nd Vice-President | David Donoghue, Texas Pacific Coal and Oil Co., Ft. Worth, Texas. |
| 3rd Vice-President | John L. Rich, Ottawa, Kan. |
| ***Districts*** | |
| Abilene | M. G. Cheney (1932), Coleman, Tex. |
| Amarillo | C. Max Bauer (1931), Midwest Refining Co., Box 972, Amarillo, Tex. |
| Appalachian | R. E. Somers (1932), Frick Building Annex, Pittsburgh, Pa. |
| Ardmore-Oklahoma City | S. H. Woods (1930), Box 296, Ardmore, Okla. |
| Canada | O. B. Hopkins (1930), Imperial Oil Co., 56 Church St., Toronto, Canada |
| Capital | H. D. Miser (1931), U. S. Geological Survey, Washington, D. C. |
| Dallas | Willis Storm (1931), 905 Exchange Bank Bldg., Tulsa, Okla. |
| Enid | Glenn C. Clark (1931), Marland Refining Co., Ponca City, Okla. |
| Fort Worth | H. B. Fuqua (1930), Box 737, Fort Worth, Tex. |
| Great Lakes | A. C. Trowbridge (1932), 1182 East Court St., Iowa City, Iowa |
| Houston | (1932), |
| Mexico | S. A. Grogan (1932), Apartado 106, Tampico, Mexico |
| New York | H. J. Wasson (1932), 25 Broadway, New York, N. Y. |
| Pacific Coast | C. R. McCollom (1931), 832 Petroleum Securities Bldg., Los Angeles, Calif. |
| | N. L. Taliaferro (1930), Bacon Hall, University of California, Berkeley, Calif. |
| | (1932), |
| Rocky Mountain | H. A. Stewart (1931), Texas Production Co., Denver, Colo. |
| | Charles M. Rath (1932), Box 240, Denver, Colo. |
| San Angelo | R. F. Imbt (1932), 1219 South David St., San Angelo, Tex. |

| | |
|---|---|
| Shreveport | W. E. Hopper (1930), 813 Ardis Bldg., Shreveport, La. |
| South America | J. B. Burnett (1930), Apartado 172, Maracaibo, Venezuela |
| Tulsa | Sidney Powers (1931), Box 2022, Amerada Corp., Tulsa, Okla. |
| | Robert J. Riggs (1930), Drawer L, Bartlesville, Okla. |
| | A. W. Duston (1932), 415 Philtower Bldg., Tulsa, Okla. |
| Wichita | Marvin Lee (1930), 612-16 Brown Bldg., Wichita, Kan. |
| Wichita Falls | C. W. Clark (1931), 717 City Bank Bldg., Wichita Falls Tex. |

## STUDIES ON THE CARBONIFEROUS OF THE MID-CONTINENT REGION

The value of exchange of ideas and of coördination of effort in carrying on a comprehensive scheme of research investigatious is now too well demonstrated to call for discussion. Nowhere have the benefits of such interchange of views and a pooling of resources accomplished more notable results than in certain projects that have been undertaken by groups of geologists belonging to the American Association of Petroleum Geologists. Recognizing these facts and counting on the willingness of a large number of workers to participate in research studies of general scientific interest and economic importance, and believing that there is a large field for such coöperative effort in study of problems relating to the Carboniferous and Permian strata of the Mid-Continent region, the possibility of working out a specific program of research in this field has been for some time in the mind of the writer.

Following preliminary negotiations of some of the state geologists, a conference was called at Norman, Oklahoma, in May, 1928, at which were present the state geologists or representatives of the State Geological Surveys of Iowa, Missouri, Nebraska, Kansas, Oklahoma, Arkansas, and Texas, also petroleum geologists and paleontologists from various parts of the Mid-Continent region representing most of the established local geological society groups. Objectives and possible means of accomplishment were considered informally at this conference and the beginning of a plan of regional organization of geologists was made. The following chairmen were designated: general, Raymond C. Moore; Texas, F. B. Plummer; southern Oklahoma, C. W. Tomlinson; central and northern Oklahoma and Arkansas, Frank C. Greene; Kansas, John R. Reeves; Nebraska, Iowa, and Missouri, G. E. Condra. Because of primary objectives in the field of stratigraphic paleontology the general chairman suggested that the proposed work might be organized under the auspices of the Society of Economic Paleontologists and Mineralogists. The regional chairmen were requested to assemble and organize local groups which could give detailed consideration and planning to work to be undertaken.

A special phase of the studies outlined, it was suggested, might consist in an attempt to tie together information concerning the subsurface extent

and character of stratigraphic divisions with surface outcrops. Accordingly a special committee on subsurface stratigraphic sections was designated, with A. I. Levorsen as chairman.

As the plan of work began to take form, it appeared to various geologists and to the Executive Committee of the American Association of Petroleum Geologists that the Carboniferous research program might advantageously be adopted formally as an enterprise of the Association, to be conducted mainly by geologists and paleontologists who are members of the Association and with the coöperation of the several state geological survey organizations. With hearty approval of the organizers of the research program, the Executive Committee of the Association, at a meeting in Tulsa, passed a resolution endorsing the Carboniferous studies and providing for connecting them with the general research program of the Association.

Following this action a meeting was called at Tulsa, January 19, 1929, of representatives of the executive committees of the American Association of Petroleum Geologists and the Society of Economic Paleontologists and Mineralogists, regional chairmen of the Carboniferous research plan, Alex W. McCoy, chairman of the Association Research committee, and representatives of state geological surveys. After beginning work in the Oklahoma-Arkansas district, Frank C. Greene was compelled to submit his resignation, and up to the present his successor in this very important district has not been designated. Following discussions it was concluded that the plan for studies in the Mid-Continent region should be correlated with the general research committee of the Association by designating Plummer and Moore as members of this general committee, which was accordingly done by President McFarland.

A report of progress in the Texas area by Chairman Plummer showed that several meetings of Texas geologists have been held, that five specific projects are outlined, and that work on some of them is well advanced. In other areas a research worker has been designated and has undertaken work on the project. The largest undertaking is the compilation of a detailed large-scale series of geologic maps of the area in which the Pennsylvanian and Permian strata are exposed at the surface, these maps showing the location of every stratigraphic unit that has been traced in field mapping. The county maps are on a scale of 4,000 feet to the inch. Approximately sixty geologists have undertaken work on this map. About fifteen county maps have been completed and work on thirty-five others is well advanced. It is planned to combine these new detailed maps on a smaller scale into a general map of the Permo-Carboniferous area.

In Oklahoma and Kansas the chief work accomplished is that in the field assigned to Chairman Levorsen, who has completed arrangements for more than twenty stratigraphic sections in Oklahoma and approximately the same number in Kansas. Ultimately it is planned to have probably one east-west section in each township and a north-south section in every third range. Standard style for the sections, arrangements to show stratigraphic rather than structural data, and, for some sections, a system of editing so as to secure most reliable data and agreement as to interpretation of the logs and of their correlations, indicate that these sections when completed will constitute a body of extremely

important data concerning the stratigraphy of a large part of the Carboniferous territory.

Plans are under way for tracing most of the stratigraphic divisions identified at type localities in Kansas and other parts of the northern Mid-Continent region southward to Oklahoma and for the making of definite detailed correlations from Nebraska to Oklahoma.

Coöperation of state geological survey agencies in the several states is indicated by tentative plans to assist in the publication, and in the attention which is being given in the survey programs to problems dealing with study of the Carboniferous areas within the respective states. The program of the survey undertakings is most advanced in Nebraska, where, in addition to a comprehensive bulletin on Pennsylvanian stratigraphy and a detailed study of the *Fusulinidae* which have appeared already, five reports dealing with Pennsylvanian fossils are now in preparation or in press.

It is hoped that through focusing the attention of geologists throughout the Mid-Continent on certain projects, some desirable stratigraphic information which is now tucked away in geologic field notebooks or in files, where it may never see the light of day, may be made available and so far as possible coördinated. Then, with attention drawn to specific unsolved problems, plans may be made for the taking up and carrying forward of particular researches. In the interest of paleontologic investigations it is very desirable to compile, as far as possible, complete data in the several areas on fossil localities. It is also very desirable that paleontologists at work on problems in this field should know the scope of the work of others and aid one another in securing complete material. Much of this very important coöperation is now being accomplished.

Finally, it is an essential part of the present program that geologists who are willing to coöperate in studies of the type planned may be made aware of such projects and that researches or parts of researches outlined may be of such scope that their undertaking and accomplishment shall be within the means of the men who enlist to do the work. Possibly one outcome of the interest of members of the Association in studies of the Mid-Continent Carboniferous may be the provision of funds which will be required for some of the investigations. A suggestion has been made that fellowships in certain graduate schools of geology may provide means for qualified university workers on projects that are being planned.

Already much has been accomplished in the way of definite results of value, and it is hoped that the program may go forward for many months with increasing accomplishment.

RAYMOND C. MOORE, *General Chairman*

UNIVERSITY OF KANSAS
LAWRENCE
January, 1929

# AT HOME AND ABROAD

## CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

The Association's new publication, *Structure of Typical American Oil Fields*, Volume 1, is now ready for distribution. The regular price is $5.00, but members may purchase copies at $4.00, postpaid. Volume 2 will be published later in the year. These volumes comprise the papers in the symposium on the relation of oil accumulation to structure.

F. G. CLAPP, consulting geologist, 50 Church Street, New York City, has an article entitled "Visit to Oil Fields in Persia and Iraq" in the *Oil and Gas Journal* of December 20, 1928.

ERNEST R. LILLEY, associate professor of geology at New York University, has an article on "Oil Reserve Situation in United States" in the *Oil and Gas Journal* of December 20, 1928.

The Association of Geophysics in Mexico was established in November, 1928, in connection with Centro Geofisico, the department of geophysics in the Petroleum School in Mexico City. The aim of the association is to help develop the methods and uses of geophysics in Mexico by coöperation of those engaged in geophysical work. It is proposed to collect the literature and arrange conferences on geophysics. A monthly bulletin will be published. The board of directors is composed of TRINIDAD PAREDES, head of the Petroleum Department of Mexico, R. MONGES LÓPEZ, representative of several petroleum companies, and JUAN KORZUJIN, professor in the Petroleum School. EDO. J. HELBLING ZIEHL is secretary. For further information write to Prof. Korzujin, Calle de Tacuba, No. 5, Mexico, D. F.

JOHN L. FERGUSON, geologist for the Amerada Petroleum Corporation at Roswell, New Mexico, has been transferred to the offices of the company at Tulsa.

CHASE E. SUTTON, of The Pure Oil Company, has been transferred from the El Dorado, Arkansas, office to take charge of the petroleum engineering staff of the Tulsa, Oklahoma, district.

JOSEPH H. SINCLAIR has contributed to the new 14th edition of the *Encyclopaedia Britannica* the section on Ecuador and the Galapagos Islands.

THOMAS CHROWDER CHAMBERLIN, professor emeritus of geology at the University of Chicago, died at Chicago, November 15, 1928.

H. E. VAN AUBEL has returned to the United States from his work in Venezuela. His address is Shell Company of California, Higgins Building, Los Angeles, California.

Carroll V. Sidwell has an article entitled "Pressure Control is Vital in Mexico," in the *Oil and Gas Journal* of December 27, 1928.

Max L. Krueger has returned from a stay of two years in Venezuela, where he was engaged in exploratory geological work for the Venezuela Gulf Oil Company. He is now with the Pacific Eastern Production Company (California subsidiary of the Gulf), 1221 Subway Terminal Building, Los Angeles, California.

Gilbert P. Moore announces the opening of an office for general consulting work in geology at 25 Broadway, Cunard Building, New York City.

Phillip Maverick, consulting geologist, Rust Building, San Angelo, Texas, mapped the geology and located the discovery well of the Empire Gas and Fuel Company on the George C. Sullivan block in Gonzales County, Texas. He was assisted by W. H. Conkling. The well was drilled on a magnetometer "high" and produced 450 barrels of 30°-gravity oil from the base of the Taylor marl at a depth of 3,779 feet.

George C. Matson has sold his interest in the Schermerhorn Oil Company and is engaged in the oil business independently, with an office at 614 Tulsa Trust Building, Tulsa, Oklahoma.

George Otis Smith, director of the U. S. Geological Survey, has an article in the *Oil and Gas Journal* for January 3, entitled "Geological Survey's Oil Studies of Great Importance to Industry."

C. R. McCollom has resigned from the Prairie Oil and Gas Company at Los Angeles, to become manager of the geological and land departments of the recently organized Pacific Western Oil Company, 832 Petroleum Securities Building, Los Angeles, California.

The Superior Oil Corporation, Texas subsidiary of the Superior Oil Producing Company, has opened a San Angelo, Texas, office for direction of operations in West Texas and New Mexico, in charge of Nathan P. Isenberger, geologist, formerly with the Amerada Petroleum Corporation. Texas headquarters are to be established at Fort Worth in the W. T. Waggoner Building, and E. C. Edwards, San Angelo geologist and a director of the Exploration Company of Texas, will go to Fort Worth about January 15 to assume charge.

E. C. Templeton, chief geologist of the Union National Petroleum Company in Venezuela, was in Los Angeles, California, on a short visit last year for the first time in two years.

Nathan W. Bass has resigned from the U. S. Geological Survey to accept a position in the geological department of The Pure Oil Company.

Marius R. Campbell, of the U. S. Geological Survey, is the new president of the Society of Economic Geologists for 1929.

Heinrich Ries, of Cornell University, has been elected president of the Geological Society of America for 1929.

Kirtley F. Mather, of Harvard University, is the new secretary of Section E (Geology and Geography) of the American Association for the Advancement of Science.

George D. Morgan, who has been vice-president of the Dixie Oil Company at Shreveport, Louisiana, during the past year, has opened a consulting office at 1305 Medical Arts Building, Fort Worth, Texas.

Carl H. Beal has resigned as vice-president of the Marland Oil Company of California and will engage in independent work in that state.

Forrest R. Rees, formerly geologist for the Oil Properties Corporation at Tulsa, has been elected president of that company.

Ben C. Belt, chief geologist for the Gulf Production Company in the north Texas district, has moved his headquarters from Fort Worth to Houston, Texas.

Withers Clay is in the employ of the geological department of the Mid-Continent Petroleum Corporation.

Hugo R. Kamb has resigned from the geological department of the Mid-Kansas Oil and Gas Company to accept a position with the Louisiana Oil Refining Corporation at Allen, Oklahoma.

# PROFESSIONAL DIRECTORY

SPACE FOR PROFESSIONAL CARDS IS RESERVED FOR ACTIVE MEMBERS OF THE ASSOCIATION. FOR RATES, APPLY TO THE BUSINESS MANAGER, BOX 1852, TULSA, OKLAHOMA

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GEOLOGIST
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# DIRECTORY OF GEOLOGICAL SOCIETIES

FOR THE INFORMATION OF GEOLOGISTS VISITING LOCAL GROUPS. FOR SPACE, APPLY TO THE BUSINESS MANAGER, BOX 1852, TULSA, OKLAHOMA

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THE KANSAS GEOLOGICAL SOCIETY SPONSORS THE WELL LOG BUREAU WHICH IS LOCATED AT 719-20 UNION NATIONAL BANK BUILDING.

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